Forest Health Technology Enterprise Team

TECHNOLOGY TRANSFER

Non-Target Impacts

Assessment of Risk to Non-Target Macro-Moths After *Bacillus thuringiensis* var. *kurstaki* Application to Asian Gypsy Moth in the Cape Fear Region of North Carolina

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Cover Photo: Venus Flytrap Moth (*Hemipachnobia subporphyrea* (Walker))

ASSESSMENT OF RISK TO NON-TARGET MACRO-MOTHS AFTER *BTK* APPLICATION TO ASIAN GYPSY MOTH IN THE CAPE FEAR REGION OF NORTH CAROLINA

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CONTENTS

INTRODUCTION

Ecological impacts of the use of the bacterial insecticide *Bacillus thuringiensis* var. *kurstaki* (*Btk*) to control the gypsy moth (*Lymantria dispar* (L.)) and other forest pests have been documented for broadleaf forest habitats in the northeastern United States (Sample et al. 1996, Wagner et al. 1996) and mixed forest habitats in the Pacific Northwest (Miller 1990a,b; Crawford et al. 1992, 1993; Crawford and Austin 1994). This study provides information on the impacts of *Btk* and efforts to mitigate these impacts within several habitats characteristic of the southeastern United States, where vegetation structure and composition, the importance of disturbance regimes, and degree of habitat degradation and fragmentation are substantially different from areas previously studied.

Asian Gypsy Moth Eradication Project

In 1994, more than 140,000 acres in the lower Cape Fear region of North Carolina (Figure 1) were treated with aerial applications of *Btk* and Gypchek to eradicate an introduction of an Asian-strain of the gypsy moth. Genetically, the gypsy moths discovered in this area actually represented a hybrid of European and Asian strains but had behavioral characteristics, particularly female flight capabilities, that phenotypically represent the Asian strain.

This Asian Gypsy Moth (AGM) Eradication Project area was located roughly 200 miles south of the front of established gypsy moth populations. Previous efforts within this general area to eradicate spot infestations of the naturalized European strain of the gypsy moth involved ground application of insecticides over areas of only a few acres. The decision to treat a much larger area in this case was based on the greater threat posed by the more dispersive and more polyphagous Asian strain and the possibility that gravid females had already spread up to 30 miles beyond the point of introduction. In 1992, an eradication effort similar in extent and intensity proved successful in preventing a similar strain from establishing in the Pacific Northwest (USDA 1992).

In 1994, approximately 138,000 acres of the project area were treated with two applications of *Btk*, and a third application was applied to 6,516 of these acres. Fixed-wing and rotary-wing aircraft flying 50-75 ft. over the canopy were used to apply 24 BIU of Foray 48B (Entotech Inc., now Abbott Laboratories, N. Chicago, IL) per application. All swaths were determined using differentially corrected global positioning system based navigation equipment. An additional 5,900 acres were treated with two applications of Gypchek and 58,000 acres were subjected to pheromone trapping.

Natural Communities of Conservation Concern within the Project Area

Broadleaf deciduous forests of the type primarily occupied by the gypsy moth in the Northeast are nearly absent within the eradication project area. Instead, the types of natural communities dominated by woody vegetation -- all targeted for treatment -- include primarily fire-maintained savannas, flatwoods, and sandhills dominated by longleaf pine (*Pinus palustris* Miller) and northern wiregrass (*Aristida stricta* Michaux); blackwater swamps composed primarily of bald cypress (*Taxodium distichum* (L.) Richard) and tupelos (*Nyssa aquatica* L. and *N. biflora* Walter); and maritime forests and peatland communities dominated by evergreen species of hardwoods and shrubs.

These natural communities are listed among the 21 most endangered ecosystems in North America (Noss and Peters 1995), a key factor for this study. Longleaf pine communities have declined by as much as 98 percent on the southeastern Coastal Plain (Noss and Peters 1995), and only about 90,000 acres of these habitats remain in relatively good condition within North Carolina (Schafale 1994). Cypress-Gum Swamps, Pond Pine Woodlands, Bay Forests, and other southern-forested wetlands have also been widely decimated; less than 20 percent may remain rangewide. In North Carolina, as much as 49 percent of all wetlands have been lost, and close to 70 percent of pocosins: – evergreen shrub bogs that are virtually endemic to the Carolinas -- have been drained and converted to pine plantations, agricultural fields, or other uses (Noss and Peters 1995). Maritime forests, grasslands, and shrub communities, along with coastal ecosystems in general, are under ever-increasing attack due to coastal development. Losses sustained in many areas of the country again range from 80 percent to over 90 percent of the original acreage (Noss and Peters 1995). In 1988, maritime forests comprised less than 7,000 acres in North Carolina (Lopanzanski et al. 1988); today far fewer acres remain, most in badly fragmented condition.

Risk to Rare Species and Fragmented Populations of Non-target Lepidoptera

Recovery of non-target Lepidoptera (moths and butterflies) from the effects of *Btk* depends on immigration from nearby, unsprayed refugia in addition to within-site reproduction by survivors (Miller 1990a,b). In a region such as the Cape Fear Region of North Carolina, where so many of the native habitats have become highly reduced and fragmented, recovery due to immigration may be particularly slow. In some cases, local extirpation might even be permanent, given that refugia are now typically miles or even tens of miles apart.

In commenting on the environmental assessment for the eradication project (USDA 1994), the North Carolina Natural Heritage Program identified 58 species of uncommon to rare Lepidoptera recorded from the vicinity of the project area, 25 of which would be potentially vulnerable to *Btk*. Among this group were two species believed to be endemic to the flatwoods and savannas of southeastern North Carolina: the Venus flytrap cutworm (*Hemipachnobia subporphyrea* (Walker)) and an undescribed species of cutworm (*Agrotis* n. sp. 1 nr. *buchholzi*). Also included were species such as the eastern arogos skipper (*Atrytone a. arogos* (Boisduval. and Leconte)) and Berry's skipper (*Euphyes berryi* (Bell)) that have more extensive geographic ranges but are known from only one or two populations within southeastern North Carolina. Since the project area contains some of the largest and best remaining tracts of Coastal Plain habitat in the Southeast (see Study Sites), there was significant concern that the project could result in population losses with major conservation consequences.

Avoidance and Minimization of Impacts

To reduce potential impacts to these species, as well as more general impacts to the distinctive ecosystems to which they belong, the North Carolina Asian Gypsy Moth Management Team (see Acknowledgments for a complete list of participants) decided to treat certain areas with Gypchek, the gypsy moth nucleopolyhedrosis virus product, which is specific in its effects on gypsy moth (Reardon and Podgwaite 1996). Areas treated with Gypchek included 18 natural areas identified by the Natural Heritage Program as having State or national significance.

Additionally, four sites within the town of Boiling Spring Lakes were treated with Gypchek at the request of the U.S. Fish and Wildlife Service, to protect several populations of the federally Endangered red-cockaded woodpecker (*Picoides borealis* (Vieillot)). Altogether, a total of 5,900 acres were treated in 1994 with two applications of Gypchek.

PURPOSE OF THE NON-TARGET STUDY

A study to monitor the impacts of the eradication project on non-target species was originally proposed by the Natural Heritage Program and was adopted as part of the project's mitigation efforts by the Asian Gypsy Moth Management Team. This report presents the results of this monitoring study, which was conducted from April 1994--shortly before the treatment project began--to June 1995, a year after the last large block of natural habitat was treated.

There were four main objectives in this study:

1. Develop a checklist of the macro-moths, a group of lepidopteran families (14 in eastern North America) that contain most of the larger and better known species of moths, found within the general region of the eradication project.
2. Identify species of macro-moths that have particular affinities for the distinctive habitats of the project area and species that are of special conservation concern.
3. Assess the overall risk to the macro-moth fauna from the applications of *Btk*, and the risk to habitat specialists and species of conservation concern in particular.
4. Compare the post-treatment abundance of macro-moths in *Btk* and Gypchek treatment blocks within representative habitat types in the project area.

This study contributes to the understanding of impacts of *Btk* on native Lepidoptera. It also provides a checklist of 668 species of macro-moths in the North Carolina Coastal Plain (Appendix B), which increases previous survey results by 276 species. This paper also rates each species according to its potential risk from *Btk* and gives the habitat range and host plants for 97 of the species, including 16 of conservation concern by the North Carolina Natural Heritage Program. Information in this report can be used to minimize the impacts of future eradication projects or to set up a large-scale monitoring program. It also will be invaluable in guiding land management decisions and setting habitat protection priorities in one of the most critical conservation areas in the southeastern United States.

TRAPPING STATIONS

The study area for the non-target Lepidoptera survey comprises Brunswick, New Hanover, and Pender Counties in the Cape Fear Region of North Carolina (Figure 1). This area includes the entire North Carolina portion of the eradication project area but excludes the adjoining extension into South Carolina.

This region is ecologically distinctive. As part of the Outer Coastal Plain Mixed Forest Province (McNab and Avers 1994), this area possesses a characteristic set of habitats that extends from southeastern Virginia to the Gulf Coast of Texas. The inland portions of this region once

supported vast tracts of longleaf pine savannas and flatwoods in the uplands and broad cypress-gum swamps in the lowlands. In the tidewater zone, maritime forests, shrublands, and grasslands covered the barrier islands typical of this region, as well as a narrow strip along the mainland coast.

This particular section of the Outer Coastal Plain has been more narrowly defined as the Outer Coastal Plain Flatwoods and Peatlands Subregion (Weakley et al. 1998). This subregion lies between the Tar River in North Carolina and the Santee River in South Carolina, and its western boundary follows the approximate line of separation between the coarse, sandy soils of the Outer Coastal Plain and the more loamy soils of the Inner Coastal Plain. Northern wiregrass is the dominant upland grass in this region -- the range limits of this plant determine the north and south limits of this subregion. As implied by the name of the subregion, pocosins, pond-pine woodlands, bay forests, and other types of peatland communities are prominent features. Overall, this region has a high degree of endemism within its plant species (Sorrie and Weakley 1998). One of its hallmark species is the Venus flytrap (*Dionaea muscipula* Ellis), which occurs only within a 90-mile radius of Wilmington, North Carolina.

Forty types of natural communities have been recorded within the eradication project area which in fact, contains one of the highest concentrations of significant natural areas and populations of rare plants and animals found in the Southern Atlantic Coastal Plain (Virginia to Florida). The Military Ocean Terminal at Sunny Point (MOTSU)--the ammunition depot where the Asian-strain gypsy moths were first detected in July 1993 -- itself contains one of the largest blocks of natural habitat remaining within this region. Over 9,000 acres are included within the Brunswick County portion of this military base, the majority of which are maintained, in natural condition, and 2,480 of these acres are in a Registered Natural Heritage Area--a site recognized by the state as having special significance for their natural features and maintained as a natural area under voluntary management agreements between the owner and the state. Other publically owned, protected natural areas within the eradication project area include Carolina Beach State Park, Fort Fisher State Recreation Area, Bald Head Island State Natural Area, Bald Head Island Coastal Reserve, and Zeke's Island Coastal Reserve. Several additional large tracts of natural habitat occur elsewhere within the treatment area but are not yet under any form of protection (Figure 1).

Wherever possible, trapping stations were placed in the center of large blocks of natural habitat, well away from paved roads and development. Appendix A lists the trapping stations, identified by locality names, and describes the habitat found in their vicinity. Figures 1-4 illustrate the location of the more important of these stations relative to the treatment areas.

Habitat descriptions generally follow the Classification of the Natural Communities of North Carolina, Third Approximation by Schafale and Weakley (1990), although in some cases we grouped communities into larger categories of more relevance for insect habitat. For instance, Longleaf Flatwood/Savanna incorporates Schafale and Weakley's Wet Pine Flatwoods and Pine Savanna natural communities; Sandhill includes Pine/Scrub Oak Sandhill, Xeric Sandhill Scrub, and Coastal Fringe Sandhill; and Maritime Forest includes Maritime Evergreen Forest and Coastal Fringe Evergreen Forest.

The habitats used for the comparison of post-treatment macro-moth abundances are described in more detail below. Three pairs of trapping stations represent matched *Btk*-Gypchek treatment blocks within three habitat types: Longleaf Flatwood/Savanna, Sandhill, and Maritime Forest. Another block in an unsprayed area served as an additional control for the Longleaf Flatwood/Savanna habitat type.

MILITARY OCEAN TERMINAL AT SUNNY POINT

The dominant vegetation at the Military Ocean Terminal at Sunny Point (MOTSU) is a mosaic of longleaf pine flatwoods, savannas, and pocosins. Some of the best examples in the state occur at this site, due to the frequency with which prescribed burning is conducted: a 5-year burn rotation is used over most of the facility.

The area treated with *Btk* includes most of the eastern section of the base, centered around the point of the Asian-strain gypsy moth introduction at the south wharf on the Cape Fear River. The trapping station within this treatment block was located in the eastern portion of the Registered Natural Heritage Area, approximately 3.5 miles NW of the south wharf. This block was treated with three applications of *Btk*, one each on April 11, 20, and 26, 1994.

The habitat within this block includes a large expanse of flatwoods. Longleaf pine is the dominant tree but is widely scattered and does not form a closed canopy. Wiregrass and shrubs, primarily heaths, are the dominant ground covers. Sand myrtle (*Leiophyllum buxifolium* (Bergius) Ellis) is common at this site, but is rare in North Carolina outside eastern Brunswick County. Forbs are fairly sparse within the flatwoods proper, but low swales scattered throughout this site contain a richer vegetation more characteristic of savanna habitats. Venus flytrap, one of the more conspicuous indicator species of this habitat type, is common near the trapping station.

The block treated with Gypchek includes the western end of the Registered Natural Heritage Area; the trapping station in this block was located approximately 3 miles WNW of the south wharf. This block was treated with two applications of Gypchek, on April 10 and 14, 1994. The habitat in this area is somewhat drier than the *Btk* block, but is dominated by the same type of flatwoods, with sand myrtle again an important element. Low swales supporting savanna vegetation are also present in the vicinity but are not as prevalent as at the *Btk* block (a few individual Venus flytraps were noted near this trapping station).

CAROLINA BEACH STATE PARK

Carolina Beach State Park is located south of Wilmington on a narrow peninsula between the lower Cape Fear River estuary and the Atlantic Ocean. The park is located opposite the northern end of MOTSU, several miles upstream from the south wharf.

The habitat within the park is much more xeric than the two trapping stations at MOTSU. The primary habitat type is Coastal Fringe Sandhills, dominated by widely spaced longleaf pines, turkey oaks (*Quercus laevis* Walter), and low thickets of scrub live oak (*Quercus geminata* Small), heaths, hollies, and other shrubs. Wiregrass and other herbaceous species are far sparser than in the flatwoods habitats found at MOTSU. Large areas of ground are covered by bare, white sand.

Btk was applied to only a small, outlying section of the park, located across a road from the main portion of the park and adjoining residential areas to the south and east. This block was sprayed with *Btk* on April 14 and 21, 1994. The dominant vegetation within this block is typical of the Coastal Fringe Sandhills habitat, as described above. A large limesink that is flooded during the winter occurs nearby. The vegetation around its rim is much more herbaceous than that found over the majority of this block.

The main part of the park was treated with Gypchek on April 9 and 12, 1994. The trapping station within this treatment block was located in Coastal Fringe Sandhills habitat similar to that of the *Btk*-treated block. A cluster of limesinks was again located nearby. In contrast to the *Btk* block, however, much more extensive tracts of this habitat adjoin this tract to the south (protected as part of the MOTSU Bufferlands, a nearly continuous strip of land running along the east shore of the Cape Fear River from the state park south to Fort Fisher, about 6 miles away). As shown in Figure 2, several large tracts within the MOTSU Bufferlands were also treated only with Gypchek.

Bald Head Island

Bald Head Island, located at the mouth of the Cape Fear estuary, once contained one of the best examples of Maritime Evergreen Forest in the state. The northernmost population of cabbage palmetto (*Sabal palmetto* Loddiges) occurs at this site in addition to extensive stands of live oak (*Quercus virginiana* Miller) and other maritime species. Most of the island, however, is now being developed, although a core of the maritime forest community is protected as the Bald Head Island Coastal Reserve, which is state-owned land administered by the Division of Coastal Management.

The area treated with *Btk* is located within the developed western portion of the island. *Btk* was applied on April 14 and 21, 1994. The trapping station within this treatment block was located at the undeveloped end of a cul-de-sac within an intact remnant of the maritime forest. A trash dump was later discovered nearby, which may have been partly responsible for the heavy beetle catches that were sporadically obtained at this trap. Data collected on some dates had to be discarded, since many of the moth specimens were mangled beyond recognition by the beetles.

The Gypchek block was located within the center of the Estuarine Reserve. This block contains the most mature and extensive block of the maritime forest habitat remaining on the island. The Reserve itself comprises approximately 200 acres of this habitat. This block was treated with Gypchek on April 8 and 11, 1994.

Boiling Spring Lakes Wetland Complex

Located less than 2 miles west of MOTSU at its closest point is a largely undeveloped area, identified by the Natural Heritage Program as the Boiling Spring Lakes Wetland Complex, that contains several of the same types of natural communities found on the military base. Although this area is privately owned, a large core section, along with significant outliers, exists in a relatively natural condition. Compared with MOTSU, however, these habitats have undergone successional changes due to prolonged fire suppression.

In 1994, the eastern portion of the Boiling Spring Lakes Wetland Complex was treated with *Btk* while the western portion was left unsprayed but subjected to intensive pheromone trapping. The trapping station established within the unsprayed block -– located approximately 5 miles west of the Gypchek trapping station at MOTSU--serves as a control for the treatment effects of both Gypchek and *Btk* at MOTSU, although the lack of frequent fire has allowed this block to become substantially shrubbier than either of the two treatment blocks at MOTSU. The dominant community in this block is again flatwoods, with sand myrtle as one of the most distinctive components of the shrub layer.

METHODS AND MATERIALS

We originally intended to include butterflies and skippers in this survey. Due to the amount of time required to handle the large volume of moth specimens, however, we decided to focus our efforts entirely on the macro-moths, a group of families (14 in eastern North America) that contain most of the larger and better-known species of moths (Covell 1984). The availability of an efficient collecting method for this group – UV light traps – also determined this selection; no comparable trapping method exists for butterflies, which are collected primarily through direct search.

COLLECTING AND IDENTIFYING SPECIMENS

Collections were obtained at weekly intervals through use of custom-built 15 W UV light traps. One light trap was located at each trapping station. Traps were left on all night to collect as many specimens as possible. While this volume of specimens is larger than may be needed for monitoring changes in abundance, it was essential to meet one of our primary objectives: to obtain a comprehensive list of species, including representatives of uncommon or rare species that might be missed by collecting during only a portion of the night (as was done, for example, by Crawford et al. 1992, 1993; Crawford and Austin 1994; and Sample et al. 1996).

All specimens were identified to species or, in a few cases, to species groups (e.g., *Crambidia pallida* complex, *Elaphria festivoides* complex). Voucher specimens were deposited primarily at the North Carolina State University Insect Collection or the private collection of J.B. Sullivan. Selected specimens have also been donated to the American Museum of Natural History, Smithsonian Institution, and Florida Collection of Arthropods.

Light trapping began in March 1994, a few weeks before the first applications of *Btk* near the South Carolina border on April 8. Moths were collected at weekly intervals from March through November in 1994 and 1995, and from March through June in 1996. Moths were also collected during the winter but only at a few stations and on a much more sporadic basis. Winter collecting was supplemented by use of baiting, involving direct collection of moths visiting patches of a fermented mixture of beer, molasses, and bananas painted on tree trunks. This technique was not used during the growing season due to the time constraints involved in the high trapping intensity and the large distances that separated the trapping stations. The checklist presented in Appendix B is based on 741 collections obtained from the light traps and 18 additional collections obtained through baiting.

During 1994 and 1995, both trapping stations in the matched pairs used in the analysis of posttreatment abundance were visited on the same night (in one instance on consecutive nights). The untreated block at Boiling Spring Lakes was also visited on the same nights as those at MOTSU, with which they were compared. Over this period, only 13 collections within this group of stations were missed or excluded due to battery failure, poor weather conditions, or heavy beetle damage.

COMPILING AND ANALYZING THE DATA

Trap data – station, date, species, and number of specimens -- were recorded in a collection records database. Two databases linked to the collection records file were used to store biological information on each species.

Categorizing Habitat Affinity and Conservation Significance

The first database was developed by the Natural Heritage Program to compile information on geographical range, larval host plants, and habitat associations for all species of macro-moths known to occur in the North Carolina Coastal Plain. Also included in this database are estimates of the rarity of the species, both rangewide and within North Carolina. These ranks are based on the number of known occurrences for a given taxon (or in some cases, on estimates of the likely number of occurrences), as well as on the quality of the occurrences, for example, population size and reproductive success rates. These ranks follow standard protocols developed by the Nature Conservancy and the Natural Heritage Program network. A description of these ranks is given in Appendix C.

Categorizing Potential Risk from *Btk*

The second database, developed specifically for this project, estimates the potential risk to each species from *Btk*. These estimates depend on information on both the length of lethal activity of *Btk*, and the life stages that would be present during that period.

Estimating the Time of Residual Activity

The active agents in commercial preparations of *Btk* include spores and diamond-shaped protein inclusions called crystals. Each crystal of *Btk* is a bipyramidal protein matrix of large molecules of inactive proteins. These are not toxic to insects until solubilized in the gut by the insect's digestive fluids and released as smaller proteins (delta – endotoxins), which are the true toxins. In most lepidopterous pests, the toxic subunits are the major cause of mortality, whereas the spore effect is minimal. Both spores and endotoxins are degraded in the environment. Exposures to ultraviolet light, temperature, humidity and leaf chemistry are all important factors governing viability.

Residual activity is usually estimated to persist for about a week, sometimes less, after single applications. However, some reports indicate activity persists for as long as 30 to 90 days after application (see reviews in USDA 1995, Johnson et al. 1995). The length of residual activity varies greatly depending on many factors, for example, species sensitivity (Johnson

et al. 1995), environmental factors as mentioned above, or on the particular formulation of *Btk* (USDA 1995). In our analysis, we assumed that the active residue period for *Btk* is no more than 10 days after the last application. More data are needed in this regard, especially where multiple applications of *Btk* are used.

Estimating Overlap of Active Residues and Larval Stages

The date of first *Btk* application was April 11 or 14, and the date of last application was April 21 or 26. Therefore, for the purposes of risk assessment, we assumed larvae that hatched after May 6 were not likely to be exposed, and that all larvae that feed between April 11 and May 6 were at risk of exposure. If the active residue period is in fact longer than 10 days, analyses based on our risk assessment could be off by a significant amount, that is, most species we scored as at risk of part exposure would be at risk of full exposure and many whose risk of exposure we scored as none would have at least part exposure.

Estimating Life Stages Exposed to Active Residues

Estimates of the life stages present coincident with active *Btk* residues were based on knowledge of the overwintering stage of the species and observations of the spring flight periods of the adults. Larval instars were extrapolated between these two stages. For example, species in the genus *Acronicta* (family Noctuidae) and in the families Sphingidae and Notodontidae are known to overwinter as pupae (except for some Notodontids that overwinter as prepupae). The egg stage of these groups ranges from 5 to 10 days depending on species and temperature. Thus if the adults begin to fly in early May, larvae will appear by mid May. Similarly all Psaphidinae and Xylenini (family Noctuidae), as well as many others, are obligate feeders on new spring growth and hatch soon after bud break around the end of March. Most of these species have to finish feeding before the leaves are fully mature.

Overwintering stages were determined from a variety of sources, including the rearing experience of the authors (mostly D.F. Schweitzer) and the literature (e.g., Forbes 1948, 1954, 1960; Crumb 1956; McGuffin 1967-1981). For species with unknown overwintering stages, the stage was inferred from closely related species, particularly congeners, since winter diapause stages are generally the same throughout a genus, or even family in some cases. We used question marks in Appendix B to indicate uncertainties.

Adult flight periods were largely determined from the data produced in this study. For certain species that were collected in small numbers -- particularly winter-flying moths -- we supplemented the study data with information from other sources, particularly Natural Heritage Program inventories conducted in southeastern North Carolina, and the personal collections and field experience of D.F. Schweitzer and J.B. Sullivan.

Two aspects of larval exposure were then estimated, with uncertainties again indicated by question marks in Appendix B. The first aspect was the proportion of a cohort present during the period of residue activity for *Btk*. We described risk of larval exposure for each species in one of three ways: (1) full exposure, if the larval feeding period fell completely within the active residue period; (2) part exposure, if the larval feeding period only overlapped the active residue period; or (3) none, if the larval period fell completely outside the active residue period.

For example, if a species overwinters as a pupa with eclosion on or after 6 May, we assumed it was not exposed to the effects of *Btk*. Conversely, if a species overwinters in the egg stage and feeds on new spring foliage of oak, we assumed it was fully exposed. Not all species fall neatly into these categories, of course, particularly species that have staggered egg hatching. In such cases we made a best approximation. If 10 percent or less of larvae were probably at risk of exposure we entered "none" in the exposure column (Appendix B). If 90 percent or more of larvae were likely at risk we entered "full," and if 11 percent to 89 percent were thought to be at risk we entered "part." In most cases, species scored as full exposure would have 100 percent exposure to at least one application. This full exposure category also includes a few species that overwinter as larvae and that would have been pupating at about the first application time (e.g., *Hemipachnobia subporphyrea*). Some individuals of these species would have been exposed as last instars, just before pupation. For individuals already in pupation at the time of first treatment, their progeny would have been affected, given the month-long period of insecticide activity produced by three successive applications of *Btk*.

The second aspect of larval exposure estimated was the range of instars that probably would be present during the period of residue activity. In Appendix B, we entered "early" where all larvae during the exposure period would be first or second instars; "late" for larvae in the last two instars; and "mid" for larvae in intermediate instars. For many species we estimated that a wider range of instars would be present. For example, we estimated that both early and mid instars would be present for *Glena cribritaria*, and mid to late instars would be present for *Scopula purata*. In a few cases where the early instars of one cohort were present along with late instars of the previous cohort, we entered "early+late".

Effects of Larval Feeding Type, Species Susceptibility and Age of Larvae

Even where larvae are present throughout the period of *Btk* activity, threats to survival depend on additional aspects of the species' biology. Two of these factors are fairly straightforward: larval feeding type and demonstrated susceptibility to *Btk*. For larvae feeding as borers or otherwise feeding on the internal tissues of their host plants (e.g., pitcher plant moths in the genus *Exyra*), we considered their risk as essentially none, even if estimated larval exposure was full during the treatment period. We were also fairly confident in assigning no risk in the few cases where the results of bioassays for *Btk* were unequivocal (e.g., the group of species determined to be insensitive, according to the criteria used by Peacock et al. 1998).

Conversely, we were confident in assessing a high degree of risk for externally feeding larvae determined to be highly sensitive based on bioassays. Examples include the species in the Noctuid subfamily Herminiinae that feed primarily on litter. Based on field observations (LaFontaine 1997) and lab assays being conducted at the University of Connecticut (Wagner and Hohn 1997), larvae in this group are sensitive to extremely sensitive in all instars.

For the vast majority of externally feeding species, however, no bioassay data are available, or the results show an intermediate level of sensitivity. For this group, we estimated the potential threat from *Btk* based on the age of the larvae that would most likely have been present when *Btk* residues were active.

A study by Peacock et al. (1998) found that almost all species he tested in the laboratory are sensitive, usually with very high mortality, as first and second instars, although there is great variability in the sensitivity of later instars (mortality zero to 100 percent), even among different species within a single genus. Other studies have also documented that younger larvae are generally more susceptible than older ones (James et al. 1993, Wagner et al. 1996). Only a very few species show greater sensitivity as older instars (James et al. 1993), although a number of species appear to be sensitive throughout their larval development (e.g., swallowtail butterflies, Johnson et al. 1995).

Estimating Overall Risk

Estimates of overall potential risk from *Btk* for each species combine all of the factors previously discussed. The following estimates are given in Appendix B:

(1) No risk: no larval instars were present during the activity period for *Btk*, if the larvae feed on internal plant tissues, or if they are rated as "insensitive" in bioassays.

(2) Possible risk: only mid to late instars were present during the activity period for *Btk* and no other mitigating factors are known.

(3) Moderate-to-high risk: early instars were present during the activity period for *Btk* but the cohort was only partly exposed; not known to be highly sensitive to *Btk*.

(4) High risk: the cohort was fully exposed and either early instar larvae were present or the species is known to be highly sensitive to *Btk*.

(5) Unknown risk: too high an uncertainty existed for us to make as estimate of potential risk.

Question marks were added to the No risk and High risk categories to indicate moderate uncertainties within the separate factors. Similar uncertainties within the Moderate-to-high risk categories were considered subsumed in the use of a range of values.

COMPARING ABUNDANCE BETWEEN *BTK* AND GYPCHEK TREATMENTS

To identify the overall effects of *Btk* on macro-moths, we compared the number of individuals trapped in blocks treated with *Btk* with the number trapped in similar habitats treated with Gypchek, which we regarded essentially as control samples, albeit treated controls rather than untreated. As mentioned in the description of Trapping Stations, three different types of habitats were used in this comparison: Longleaf Flatwood/Savana, Sandhill, and Maritime Forest. An additional untreated control block was available in the Longleaf Flatwood/Savana category.

Interpretation of the results of these comparisons is complicated by several limitations of our study. First, our decision to rely solely on collections of adult moths, which was done to maximize the number of species identified within the habitat units, introduces a large number of sampling errors not associated with the more direct collection of larvae (Butler and Kondo 1991). Sample et al. (1996), however, observed similar effects of *Btk* in light trap collections of adults as in direct collections of larvae, although the effects among the adults were not as pronounced as among the larvae.

Second, given the highly varied habitats of the project area, it was difficult to find trapping stations that matched closely in terms of vegetation composition, maturity, and extensiveness. The decision to treat nearly all the high quality habitat blocks identified by the Natural Heritage Program with Gypchek further complicated the task of finding matching trapping stations within the *Btk*-treated blocks. In any case, too few collections were obtained before spraying commenced to verify the underlying similarities of the macro-moth faunas within the treatment blocks to be compared. Any differences observed between blocks could therefore be due as much to habitat differences as to treatment effects.

Third, we decided to maximize the number of collection intervals and habitat types included in the survey at the expense of replications within treatment blocks; this decision decreased the overall power of our analysis, ruling out the use of such methods as analysis of variance. As it turns out, we probably would have required a large number of replicates in order to sort out all the habitat and weather factors that seemed to be at work in addition to the treatment effects.

RESULTS

Assessment of Habitat Association and Conservation Concern

A total of 54,504 specimens of macro-moths were collected, 95 percent of which were identified to species. The resulting checklist, presented in Appendix B, includes 668 species belonging to 330 genera and 11 families. This total represents an increase of 276 species over the results obtained by Hall and Schweitzer (1993), who conducted the only previous survey of macro-moths within the eradication project area.

Sixteen species, listed in Appendix D, appear to represent new records for the state. The most surprising of these is the globally rare rattlesnake-master borer (*Papaipema eryngii* Bird). Major range extensions (from farther than one state away) were also recorded for nine other species, which include a number of southern species not previously documented north of Florida. Together with data provided by Natural Heritage Program inventories of the macro-moths at Camp Lejeune Marine Corps Base and collections made by J.B. Sullivan in the Croatan National Forest and vicinity (both to the north of the AGM project area), the overall checklist of macro-moths for this region now stands at roughly 900 species.

The majority of the species we collected range widely over the eastern United States and are associated with fairly generalized habitats, including hardwood forests, pinewoods, old fields, and other types of disturbed habitats. Individually, the species in these habitat groups are not of any great conservation concern, although wholesale reduction within this group is likely to have wide ecological repercussions.

As stated in the Introduction, we were primarily interested in the species associated with the more distinctive habitats found within the Cape Fear Region. Appendix C lists 99 of these species, along with 7 additional species that are considered rare in North Carolina but for which habitat affinities are either less well understood or that are of relatively minor extent within the study area.

Longleaf Pine and Wiregrass Habitats

Many of the most distinctive species of plants and animals found within this region are associated with longleaf pine-dominated habitats. Due to the catastrophic reduction of these habitats, as well as to the effects of fire suppression, many of these species are also now rare throughout their range. Longleaf-dominated habitats range from wet savannas to xeric sand-ridges, each with a distinctive fauna of macro-moths, which are discussed separately below. Additionally, a small group appears to be associated with these longleaf habitats more generally. Two of these species, *Semiothisa distribuaria* (Hubner) and *Tolype minta* Dyar probably feed on longleaf pine. *Euagrotis lubricans* (Guenee) and *Gabara pulverosalis* (Walker) may be specialists on wiregrass.

Both of the species in this group considered significantly rare by the Natural Heritage Program, *Euagrotis lubricans* and *Gabara pulverosalis*, were recorded within the Gypchek and *Btk* blocks at MOTSU and Carolina Beach State Park during the post-treatment period in 1994.

Savannas

Twenty species collected in this survey appear to be associated with Pine Savanna habitats, the wet extreme of longleaf pine-dominated communities. In other regions of the eastern United States, several of the species in this group are associated with open bogs or other types of moist, native grasslands. The host plants of virtually all these species are believed to be herbaceous--a species of forb, grass, or sedge. Within the context of savannas, at least, most of these plants require frequent fire to maintain the open habitats they depend upon.

Two of the species in this group are among the rarest moths known in North America. The first, and perhaps most distinctive of this entire region, is the Venus flytrap cutworm (*Hemipachnobia subporphyrea* Walker). Like its host plant, this moth appears to be endemic to North Carolina. Apart from two specimens in the British Museum that were collected in the late 1770's (Hampson 1903), all other specimens have been collected only since the 1970's, from just eight sites in North Carolina. Eleven specimens were collected during this survey: a single specimen was collected from the *Btk* treatment block at MOTSU in 1994; two were collected from the Gypchek treatment block in 1995; and the remainder were collected at three different trapping stations in the Holly Shelter Game Lands in 1995 and 1996.

The second highly rare species is the rattlesnake-master borer (*Papaipema eryngii* Bird), a species previously known only from the prairies of the Midwest and once thought to be extinct. Only three or four other populations of this species are now known to exist, all west of the Appalachians. Although the host plant for this species, *Eryngium yuccifolium* Michaux, has been recorded over most of the Coastal Plain and Piedmont of North Carolina, significant concentrations -- such as are probably required to maintain a population of the moth -- are known from relatively few sites. Populations of this plant in the Outer Coastal Plain, representing a distinct variety (*E. yuccifolium* var. *synchaetum* (Gray) C.& R.), appear to be strongly associated with the Very Wet Clay Variant of Pine Savannas, a rare natural community that is home to several of the state's rarest plant species. The single moth collected during this survey at an untreated area was taken in this type of habitat. A larva subsequently collected at the same site by J.B. Sullivan and Eric Quinter (American Museum of Natural History), confirmed the host plant to be *Eryngium yuccifolium*.

All three of the other species in this group considered significantly rare in North Carolina by the Natural Heritage Program – *Gabara distema humeralis*, *Exyra semicrocea*, and *Spartiniphaga carterae* – were collected after treatment in 1994 from the *Btk* treatment block at MOTSU.

Flatwoods

Relatively few species on our list are associated with flatwoods *per se*. The larvae of most of the species characteristic of these habitats feed on shrubs, including blueberries and other heaths, hollies, and wax myrtles, all of which are highly typical of these habitats but also occur in a variety of other habitats. Most of the species in this group that are of special conservation concern are listed under Shrubby Peatlands in Appendix C. Only the following four species appear to be particularly associated with flatwoods habitats: *Cyclophora culicaria, Datana ranaeceps, Agrotis* n. sp. nr. *buchholzi*, and *Acronicta sinescripta*.

Cyclophora culicaria (Guenee) is found in close association with sand myrtle (*Leiophyllum buxifolium* (Bergius) Ell.), a heath with a highly restricted distribution in North Carolina. This plant is most abundant in the flatwoods in Brunswick County, particularly at MOTSU and the Boiling Spring Lakes Wetland Complex, the only areas where this moth has been found in the state so far. Like its host plant, *C. culicaria* is one of the most conspicuous species in these areas. Specimens were found in nearly every collection at MOTSU and the Boiling Spring Lakes area, including *Btk* treatment blocks as well as Gypchek treatment blocks and untreated blocks.

The larvae of *Datana ranaeceps* (Guerin-Meneville) feed on two genera of heaths, *Lyonia* and *Leucothoe*, which are common in both peatland and flatwood habitats. The larvae of this moth appear to require the fresh foliage produced after a fire, however, and nearly all of our records are from frequently burned flatwoods at MOTSU and Holly Shelter Game Lands. During the post-treatment period in 1994, specimens were collected at both *Btk* and Gypchek treatment blocks, although in May and June specimens were collected only at the Gypchek block.

The new species of *Agrotis* appears to be a close sibling to *Agrotis buchholzi* (Barnes and Benjamin), a species endemic to the pine barrens of New Jersey (Schweitzer and McCabe 1998). Like true *buchholzi*, the new *Agrotis* appears to be monophagous on pixie moss (*Pyxidanthera barbulata* Michaux), a low-growing plant that requires frequent fire to maintain its habitat. In the Outer Coastal Plain, this plant is one of the species most highly restricted to flatwoods (another variety occurs in the Sandhills in more xeric situations). This moth, along with the Venus-flytrap cutworm, appears to be endemic to North Carolina. Twenty six specimens were collected in this survey, from flatwood sites at Holly Shelter Game Lands, the Green Swamp, MOTSU, and Boiling Spring Lakes. At MOTSU, a single specimen was collected in the *Btk* block before treatment and a second specimen was collected there a year later. In the Gypchek block, specimens were collected in 1994 both before treatment and during the summer flight period in 1994. *Agrotis* was also collected in this block during spring 1995.

Acronicta sinescripta Ferguson is tentatively placed in the flatwood group, since North Carolina specimens have all come from flatwoods or fire-suppressed (hence shrubby) savannas. The host plant is unknown. Based on the larval hosts of two closely related species, *A. oblinita* (J.E. Smith) and *A. lanceolaria* (Grote), the host plant could be a shrub, forb, or graminoid. Only two specimens were collected in this survey, both from the Holly Shelter Game Land outside the eradication project area.

Shrubby Peatlands

Shrubby peatlands include pocosins, pond-pine woodlands, and bay forests, all of which occur in very poorly drained sites where deep deposits of peat have formed. In some of these habitats, canopies may be composed of pond pine (*Pinus serotina* Michaux), swamp bay (*Persea palustris* (Rafinesque) Sargent), or other trees, but in all cases the lower strata of the vegetation are dominated by thick growths of heaths, hollies, and other evergreen shrubs.

As is true for moths of flatwoods habitats, many of the most characteristic species of shrubby peatlands are found in other types of natural communities where their host plants are present. In general, this group of moths has probably suffered less from habitat loss and fragmentation than has the savanna or flatwoods group. Several species, however, appear to be far more restricted than the distribution of their host plants would indicate. The sweetbay silkmoth (*Callosamia securifera* Maasen), which is monophagous on the widespread sweetbay (*Magnolia virginiana* L.), is a good example.

Of the four species considered significantly rare in this habitat group by the Natural Heritage Program, only *Metarranthis lateritiaria* Guenee was collected at the trapping stations used in the comparison of *Btk* and Gypchek treatment effects. This univoltine, spring-flying species was collected after treatment at both Gypchek and *Btk* treatment blocks at MOTSU.

Atlantic White Cedar Forests

Stands dominated by Atlantic white cedar (*Chamaecyparis thyoides* (L.) BSP) represent another type of peatland community. Along with pocosins, bay forests, and nonriverine swamp forests, this community type was once widespread in the Coastal Plain of North Carolina. It is now, however, considered among the most threatened types of forest in North Carolina, due to the over-harvest of this valuable commercial timber species and suppression of fire on which it depends for regeneration.

Most of the moths associated with Atlantic white cedar, on the other hand, are not that rare, since they can also feed on eastern red cedar (*Juniperus virginiana* L.), a species widespread over most of eastern North America. One possible exception is *Hypagyrtis brendae* Heitzman, a species previously known only from the Mississippi Valley. The host plant has not been confirmed, but in North Carolina this species is abundant in stands of white cedar, while virtually none have been collected from areas occupied by the more ubiquitous red cedar.

All members of the Atlantic white cedar habitat group, along with Hessel's hairstreak (*Mitoura hesseli* Rawson and Ziegler), a butterfly documented as monophagous on Atlantic white cedar, were collected at both of the trapping stations in white cedar, at Green Swamp and Holly Shelter Game Lands, which were both outside the treated areas.

Canebrakes

Eric Quinter (1997) has discovered a large array of noctuids that are apparently monophagous on cane; several of these species are undescribed, as are four of the genera to which several belong. Although cane itself is still common, at least a few of these species appear to be rare, possibly resulting from the demise of the once vast canebrakes of the southeast (Quinter 1997). The two species of cane-feeding moths we obtained in this survey, however, appear to be among the least selective of the kind of cane habitats they choose. Nonetheless, both *Acrapex relicta* Ferguson and

Amphipyrinae (Noctuidae), New Genus 2, New Species 2 were collected only at trapping stations in the Holly Shelter Game Lands.

Swamp Forests and Levee Forests

Another group of macro-moths that is narrowly restricted in their choice of larval host plants is composed of species that feed on cypress (probably including bald cypress, *Taxodium distichum* (L.) Richard and pond cypress, *T. ascendens* Brongniart). Although large tracts of cypress-gum swamps have been timbered or otherwise significantly altered, cypress remains common throughout the region. So do most of the moths that feed upon it. The most noteworthy species in this guild is *Anacamptodes cypressaria* Grossbeck, which until collected by Hall and Schweitzer (1993) in Brunswick County, North Carolina, was not known north of Florida (Rindge 1966). In contrast to *Anacamptodes pergracilis* (Hulst), another cypress-feeding species that is widespread throughout the region, *A. cypressaria* appears to be much more local in its distribution, although it is occasionally abundant at the sites where it does occur. This species has been collected at only three trapping stations within the non-target study area, all outside the eradication project treatment area.

The two other noteworthy species belonging to this habitat group are *Catocala lincolnana* Brower and *C. marmorata* Edwards. The host plants of *C. lincolnana* include swamp species of hawthorns (*Crataegus* spp.), and swamp cottonwood (*Populus heterophylla* L.) is the host for *C. marmorata*. These plant species are common along the levees and swamp forests of the Cape Fear River, the one brownwater river within the project area, but are rare or absent from blackwater swamps, which are the more prevalent type of swamp forest in the North Carolina Coastal Plain. Brownwater rivers originate in the Piedmont or Blueridge physiographic provinces and carry large amounts of sediments. Blackwater rivers, in contrast, originate in the sandy soils of the Coastal Plain and contain smaller sediment loads.

Both *C. lincolnana* and *C. marmorata* were recorded during the study at Greenbank Bluff, well outside the eradication project area; *C. marmorata* was also collected from a swampy area within the Gypchek treatment block at Carolina Beach State Park. Outside the study area, both species have been collected in floodplain habitats along the Roanoke River, another large brownwater river that flows through the North Carolina Coastal Plain (Hall 1999).

Sandhills

The largest group of habitat specialists in the eradication project area -- 24 species of macro-moths -- is associated with the most xeric habitats found within the region. In the Outer Coastal Plain of North Carolina, xeric areas are almost exclusively associated with sandhills and are dominated by longleaf pine, wiregrass, and turkey oak. Other xeric oaks and shrubs may also be important elements. Elsewhere, many of the moth species associated with these habitats occur in more general types of pine-oak barrens or dry, open woodlands.

Sandhills habitats are fairly widespread within the Cape Fear region but have been largely degraded or converted by timbering, development, and fire suppression. Most of the moths associated with these habitats were collected in the large, high quality tracts at Carolina Beach State Park and Peter's Point in the MOTSU Bufferlands. Of the six species in this group considered significantly rare by the Natural Heritage Program, all but *Pygarctia abdominalis* Grote were collected at Peter's Point, an area in the MOTSU Bufferlands treated with Gypchek. *Catocala amestris* Strecker and *C. jair* Strecker

were collected only at Peter's Point. Two of the six species were also collected within Carolina Beach State Park: *Ptichodis bistrigata* Hubner was collected in both the *Btk* and Gypchek blocks in 1995, and *Trichosilia manifesta* (Morrison) was collected in both treatment blocks in 1994 and 1995.

Maritime Evergreen Forests and Scrub

In North Carolina, forests dominated by live oak (*Q. virginiana* Miller) are largely confined to the barrier islands and a few sites along the outer coast; only a few small isolated stands occur further inland. Maritime shrub habitats, dominated by sand live oak (*Q. geminata* Small) and other species of shrubs, are also limited to the Outer Coastal Plain.

Most of the moths in this habitat group feed on evergreen oaks, which include sand laurel oak (*Q. hemisphaerica* Bartram) in addition to live oak and sand live oak. A few species in this group feed on other plants typical of the maritime zone. These include *Litroposopus futilis* (Grote and Robinson), that feeds on palmettos, and *Drasteria graphica* Hubner, which in southeastern North Carolina may feed on a maritime species of sunrose (*Helianthemum*).

The species in this group considered significantly rare in North Carolina by the Natural Heritage Program are all apparently associated with maritime shrub communities and were collected primarily at Peter's Point in the MOTSU Bufferlands and at Carolina Beach State Park.

Drasteria graphica was recorded within the *Btk* treatment block at Carolina Beach State Park only in the pretreatment period in 1994, but was collected in the Gypchek treatment block in 1994, 1995, and 1996. It was also collected at Peter's Point in 1994 and 1995 and in the Gypchek block in the main portion of MOTSU in 1995.

Zale declarans (Walker) was collected in both treatment blocks at Carolina Beach State Park, before and after treatment in 1994, 1995, and 1996. It was also commonly collected at Peter's Point and Fort Fisher (Gypchek treatment blocks) and once in the *Btk* treatment block at Bald Head Island before treatment.

Catocala messalina Guenee was collected once in the *Btk* treatment block at Carolina Beach State Park, after treatment in 1994. All other records come from Peter's Point during the posttreatment period, four from 1994 and one from 1995.

Mesic Hardwood Forests

Stands of mesic hardwoods are rare within the Outer Coastal Plain and only four species recorded in this study appear to be restricted to this type of forest (a larger number are associated with hardwoods more generally). These species were all recorded at Greenbank Bluff, the one site in the non-target study area containing this type of habitat. *Scopula ordinata* (Walker), which feeds on *Trillium catesbaei* Elliott (Covell 1970), was recorded only at this site, which is one of the few areas in the entire Outer Coastal Plain likely to support populations of this host plant. The other species were also collected at trapping stations containing bottomland hardwoods, but not within the eradication project area.

Other Species of Conservation Concern

Several rare species for which habitat requirements are poorly known are included at the end of Appendix C. *Eupithecia peckorum* was recorded within the *Btk* block at Carolina Beach State Park before treatment but not after. It was also recorded at Fort Fisher and Peter's Point (both *Gypchek* blocks) after treatment, as well as at two sites outside the treatment area. *Dysgonia smithii* was recorded at Half Hell Swamp, a *Btk* block, after treatment. It was also recorded at two additional sites outside the treatment area. *Cerma cora* was recorded only at Fort Fisher and Peter's Point, both before treatment with Gypchek. *Meropleon diversicolor sullivani* was recorded only once, at the *Btk* block at Half Hell Swamp after treatment. *Ceratonyx satanaria*, *Macrochilo louisiana*, and *Lithophane laceyi* were recorded from the eradication project area but from outside the treatment area.

ASSESSMENT OF POTENTIAL RISK FROM *BTK*

Risk to All Macro-Moths

Appendix B lists all species of macro-moths collected in this survey, along with the *Btk* risk assessment criteria described in Methods and Materials. The following table presents the tallies for each risk group:

All Macro-Moths

POTENTIAL RISK FROM *BTK*	NUMBER OF SPECIES
Unknown Risk	75 (11%)
No risk	158 (24%)
No risk?	29 (4%)
Possible risk	72 (11%)
Moderate-to-high risk	174 (26%)
High risk?	9 (1%)
High risk	151 (23%)

Although these figures represent potential risk in the majority of cases, we are confident that only a small proportion of the overall macro-moth fauna within the eradication project area are probably at no risk from the application of *Btk*. Species in this group were either not present as larvae during the time of spraying, feed within their host plants, or have low effects of *Btk* in bioassays.

Of the species for which we were able to estimate the instars that would have been present during the application period, the vast majority -- 50 percent of all species identified in the survey -- appear to be at substantial risk, scoring a risk of either moderate-to-high or high. Most of these species would likely have been present as early instars during active *Btk* residue. Other species in this risk group are those with known high susceptibility to *Btk*.

A much more limited group -- 11 percent of the total -- was more likely to have been present as mid- to late-instars and fall into the "Possible Risk" category. Although we believe these species are less likely to be affected, there are undoubtedly some highly sensitive species included in this group.

Risk to Habitat Specialists and Rare Species

The following table presents the risk analysis for just the group of habitat specialists and rare species listed in Appendix C, that is, the group for which our concerns were the greatest:

Habitat Specialists and Rare Species	
POTENTIAL RISK FROM *BTK*	**NUMBER OF SPECIES**
Unknown risk	19 (18%)
No risk	17 (15%)
No risk?	2 (2%)
Possible risk	15 (14%)
Moderate-to-high risk	28 (26%)
High risk?	0 (0%)
High risk	25 (24%)

Again, only a small percentage – 19 percent -- appears to be at little or no risk. Several of the rarest species in the region belong to this group, however, including the following species identified as significantly rare in North Carolina by the Natural Heritage Program:

Acronicta sinescripta Ferguson
Anacamptodes cypressaria (Grossbeck)
Exyra semicrocea (Guenee)
Meropleon diversicolor sullivani Ferguson
Metarranthis n. sp. 1
Papaipema eryngii Bird
Spartiniphaga carterae Schweitzer
Notodontidae, n. genus 1, n. sp. 1

Four of these species are internal plant feeders: *Exyra semicrocea, Meropleon diversicolor sullivani, Papaipema eryngii*, and *Spartiniphaga carterae*. The others were probably not present as larvae during the spray period.

As in the case of the entire fauna, the majority of the habitat specialists appear to be at moderate-to-high risk. Of the subset of this group considered significantly rare by the Natural Heritage Program, the following species are estimated to be at high risk from *Btk*:

Agrotis n. sp. 1 nr. *buchholzi*
Catocala jair Strecker
Ceratonyx satanaria Guenee
Cerma cora Hubner
Chaetaglaea fergusoni Brou
Cyclophora culicaria (Guenee)
Drasteria graphica Hubner
Eupithecia peckorum Heitzman and Enns
Hemipachnobia subporphyrea Walker
Ptichodis bistrigata Hubner
Pygarctia abdominalis Grote
Trichosilia manifesta (Morrison)

For most of these species, the trapping data collected in this study offers little conclusive evidence regarding their actual sensitivity to *Btk*. The majority is represented by five or fewer specimens collected within the treatment area and several of these species were not found within the matched habitat blocks used to compare *Btk* and Gypchek treatments.

Five of these species, *Agrotis* n. sp. 1 nr. *buchholzi*, *Cyclophora culicaria*, *Pygarctia abdominalis*, *Ptichodis bistrigata*, and *Trichosilia manifesta*, were found after treatment with *Btk*, although in some cases only a year later. This suggests that population recovery was at least possible, whatever the impacts of the spraying may have been. On the other hand, adults of *Hemipachnobia subporphyrea* and *Drasteria graphica* were recorded before treatment with *Btk* but not after (both species were found in Gypchek blocks after treatment). For these species in particular, more trapping is needed to determine whether their populations eventually recovered.

COMPARISON OF ABUNDANCE BETWEEN TREATMENTS

Figures 5-7 plot the weekly changes in overall macro-moth abundance in 1994 and 1995 within the three pairs of trapping stations for the matched *Btk* and Gypchek blocks. Also plotted are the dates of the initial application of *Btk* for each of the station pairs, along with an estimated 2-week lag period, within which no effects of the spraying are likely to show up. Species exposed as late instars would be the first to show any effects, as soon as they begin to emerge from pupation. Given a minimum of 2 weeks for pupation in most macro-moths during spring, no effects would be likely to show up among the adults for at least this period.

Pretreatment Comparisons

Pretreatment abundance levels from the two MOTSU treatment blocks were very similar (Figure 5): the *Btk* block produced more specimens on two of the trapping dates and the Gypchek block more on the other two dates. Apart from one collection in late March, pretreatment abundance levels from the two treatment blocks at Carolina Beach State Park also were similar (Figure 6), although blocks later treated with *Btk* consistently produced more moths. These similarities in

abundance between the treatment blocks at MOTSU and Carolina Beach State Park are in accord with the general similarities in habitat observed in these areas, as described under Trapping Stations.

On the other hand, pretreatment abundance levels from the treatment blocks at Bald Head Island differed substantially. The Gypchek treatment block consistently produced more moths (Figure 7). This result agrees with differences in habitat features recorded at the two stations: the Gypchek block was located in an essentially intact maritime forest, whereas the *Btk* block was located within a developed area, where light pollution may have affected trapping efficiency or, along with other factors, degraded the habitat for macro-moths.

General Posttreatment Trends

A comparison of data from MOTSU and from similar habitats in the same region obtained in 1991 (Hall and Schweitzer, 1993) indicates that a major depression in macro-moth abundance occurred independently of treatment effects shortly after spraying commenced. A plot of trends in abundance at MOTSU and at four Nature Conservancy Preserves, which also consisted of a mosaic of longleaf pine-dominated habitats and peatland communities, were comparable in early April (Figure 8). Levels of abundance at MOTSU were much lower over the rest of the year, however, particularly during May, July, and August.

As shown in Figure 9, these trends were not limited to areas treated with *Btk* or Gypchek: numbers comparable to those at MOTSU were also recorded at the trapping station in the Boiling Spring Lakes Wetland Complex, outside the treatment areas but in habitat similar to that at MOTSU and the Nature Conservancy trapping stations. The same general trends were also seen at other stations in 1994, in habitats for which we have no other baseline data. The changes in abundance observed within the Coastal Fringe Sandhills habitats at Carolina Beach State Park, for instance, closely match those at MOTSU (compare Figure 5 and 7): the abundances within both treatment blocks declined markedly in early May and stayed low throughout most of the summer.

One factor that could explain low lepidopteran abundance over a large region is adverse weather, particularly periods of either cool, moist weather or hot, dry weather (Sample et al. 1996). Figures 10 and 11 show monthly averages for rainfall and temperature within the eradication project region for 1991, the year of the Nature Conservancy survey, and 1994. Two major differences show up during spring:

1. April 1994 appears to have been markedly drier and somewhat hotter than April 1991.

2. The average low temperature for May was 8 ° F cooler in 1994 than in 1991, the result of a series of moderately cooler days rather than a cold snap (Figure 12).

Activity among moths has been demonstrated to depend on temperature. We would expect the cool period in May to result in a lower number of moths collected, however, no similar cool period occurred during summer that would account for the lower numbers that prevailed from June to September 1994. Larval mortality may also have been involved, probably occurring at some point before the decline in abundance among the adults.

Posttreatment Comparisons

Despite the fact that moth numbers appeared to be abnormally low in all treatment blocks in 1994, abundance within the *Btk* blocks was generally lower to much lower than in the matching Gypchek blocks. This pattern is shown in weekly trends in abundance (Figure 5-7), as well as in yearly totals (Figure 13).

The differences between treatments were particularly noticeable at Carolina Beach State Park, where before the end of the lag period all collections consistently showed greater abundance within the *Btk* block, but afterwards nearly all showed smaller catches (Figure 6). Within 1994, this difference appeared to persist into September, after which the collection from the *Btk* block once again became larger. In early 1995, however, collections from the Gypchek block were again larger, corresponding to the emergence period for a number of univoltine, spring-flying species that would have been exposed as larvae during the previous year. The cumulative effect of these weekly differences in abundance is shown in Figure 13, where the combined collection from the Gypchek block are larger than those from the *Btk* block in both 1994 and 1995.

A similar pattern after treatment was seen at Bald Head Island in 1994 and 1995 (Figure 7), although -- as mentioned previously -- the Gypchek block may have been located in better habitat, as indicated by the pretreatment effects. The smaller collection in the *Btk* block at Bald Head Island thus cannot be completely attributed to treatment effects.

The collection from MOTSU (Figure 5) likewise show the same trends during the posttreatment period, although otherwise the collections appear to be more similar than those from the other two stations. Perhaps due to this greater similarity, the period during which the collections from the Gypchek treatment blocks were consistently larger appeared to last for a shorter period of time at MOTSU, extending only until the end of July 1994 and to the end of May 1995.

Between-Year Changes in Abundance

Increases in moth numbers from 1994 to 1995 occurred at three of the treatment blocks within the group of matched habitat pairs (Figure 13): the Gypchek blocks at Carolina Beach State Park and MOTSU, and the *Btk* block at MOTSU. Increases were also observed at Peter's Point in the MOTSU Bufferlands (treated with Gypchek) and at International Paper (IP) in the Boiling Springs Lake Wetland Complex (treated with *Btk*). Apart from the fact that all of these blocks are dominated by longleaf pine communities, ranging from xeric sandhills to wet pine flatwoods, the most obvious common denominator is the extensiveness -- several thousand acres -- of natural habitat.

Moth numbers decreased at both treatment blocks at Bald Head Island, at the *Btk* block at Carolina Beach State Park, and at the Gypchek treated block at Fort Fisher. The *Btk* block at Carolina Beach State Park as described previously, is longleaf pine-dominated sandhills, while the other habitats are all maritime forest. Compared with the large areas of habitat present at all of the trapping stations where numbers increased, these four stations can all be considered small and insular. For the three maritime forest stations, areas of comparable habitat are located some distance away, separated by water, development, or large tracts of other types of habitat (Figure 2). The *Btk* block at Carolina Beach State Park is located on the periphery of the major block of sandhills habitat in the area and is surrounded on all sides by roads or development.

DISCUSSION

Previous Non-target Studies

Most previous studies of the non-target impacts of *Btk* were concerned primarily with general effects on the entire lepidopteran fauna or taxonomically defined subsets, and the principal effects investigated included changes in the abundance of individuals or in total number of species (i.e., species richness). Although these studies acknowledge that impacts may be greater on rare species and that recolonization from untreated refugia plays a role in recovery from impacts -– which were the two main foci of our project -– only a few have investigated these effects directly.
In a study of the guild of Lepidoptera feeding on Garry oak (*Quercus garryana* Dougl. ex. Hooker) on plots treated with three applications of *Btk*, recovery in the number of species took 3 years, while recovery in the number of individuals took only 2 years (Miller 1990a). This result is contrary to the expected relationship between species richness and sample size: the number of species usually varies directly with the number of individuals collected. Miller (1990a) hypothesized that this difference reflected the slower rate of recolonization needed for species recovery compared with the more rapid within-site reproduction by survivors that accounted for recovery in gross abundance.

In a second study conducted on a guild of Lepidoptera feeding on tobacco brush (*Ceanothus velutinus* Dougl.), Miller (1990b) found that species richness among uncommon species was reduced on treated plots, although no significant differences were found among common or dominant species. He hypothesized that rare species were particularly vulnerable to local extirpation, or even extinction in the case of species endemic to the treated area. On the basis of these findings, but not on any direct data, he further suggested that the larger the area treated, the longer recovery would take, due to the greater time needed for recolonization to extend into the treated areas from unsprayed refugia (Miller 1990a, b). Although not studied directly, this idea has been subscribed to in other studies of non-target impacts of *Btk*, for example, Peacock and Bullington (1989), Wagner et al. (1996), and Sample et al. (1996).

In the study most similar to ours, Crawford et al. (1992 1993; Crawford and Austin 1994) monitored the impacts to non-target species of large scale, multiple applications *Btk* to eradicate Asian-strain gypsy moths in Washington State (USDA 1992). As in our study, the potential impacts to natural areas and to rare moth species were of high concern. Spring-flying moths collected over a variety of native habitats were categorized according to their degree of abundance, vagility, and narrowness of distribution.

Of 68 spring-flying species recorded, 14 were judged to be both local in distribution and either uncommon or rare. Based on the early flight period of the adults, all were also expected to have been present as larvae during the time of spraying. Compared with more vagile species (including uncommon but widespread species), which were expected to recolonize treated areas relatively rapidly, the group of uncommon, local species was expected to take several years to recover to baseline levels. The majority of these species were not, in fact, re-collected during spring 1 year after treatment, although differences in rates of recovery between the different categories are still not clear. A full analysis of the data from spring 2 years after treatment has not yet been completed, but at least one very rare and highly localized moth, *Protorthodes rufula* (Grote), reappeared at its original site in the third year of this study, after having been missed the two preceding years.

THE PRESENT STUDY

In our study, we also grouped species into categories that we believed would respond differentially to the effects of *Btk*. Unlike Miller (1990a, b), Crawford et al. (1992, 1993), or Crawford and Austin (1994), we attempted to categorize the entire fauna of macro-moths found within our project area. In addition to grouping species according to their degree of rarity (including consideration of both spatial distribution and local abundance), we also characterized species according to habitat affinity and to potential risk from *Btk*, based on larval phenology and feeding type. Given the extreme level of habitat fragmentation in our study region, we expected that species with high affinities to the native habitats would be particularly slow to recover from the effects of reductions in their populations, since recolonization may play little or no role in recovery. This group should also contain a disproportionate number of species at high risk of local extirpation.

Of the 106 macro-moths we identified as habitat specialists or as otherwise of particular conservation concern (Appendix C), we estimated 53 species -- 8 percent of the total number of macro-moths collected -- fall within the moderate-to-high or high risk categories. Based on the high degree of reduction and fragmentation of native habitats within southeastern North Carolina, we expected this proportion to be higher than for areas with more homogeneous and less-fragmented habitats. However, there are no other studies to which we can directly compare these results. As mentioned above, Crawford et al. (1993) identified only 14 species of localized or rare moths within spring-flying moths believed to be at greatest risk, but used methods of categorizing risk and distributional status that were substantially different from those of our study.

Although we estimated only a small proportion of the entire fauna of macro-moths would be particularly at risk, this group contains the two species believed to be endemic to southeastern North Carolina, *Agrotis* n. sp. 1 nr. *buchholzi* and *Hemipachnobia subporphyrea*, as well as several other species known from only locations within this region. Loss of any populations of these species would be of significant conservation concern, but loss of even a single population of *Hemipachnobia subporphyrea* could be catastrophic for this species. Based on results of a status survey currently being conducted by the Natural Heritage Program, only four extant metapopulations are known, including the one present at MOTSU within the eradication project area.

Our analysis of impacts to 12 rare species in the high risk category failed to show any definite trends, primarily due to the low numbers of individuals of these species captured within the *Btk* and Gypchek comparison blocks. Analysis of impacts to the overall fauna of macro-moths, however, strongly suggests an effect due to *Btk*, as would be expected based on our estimates that 50 percent of the species would be at moderate-to-high or high risk. Although there appear to have been additional, unexplained factors affecting posttreatment abundance levels in 1994, our results are consistent with findings of previous field studies of the non-target impacts of *Btk*. Virtually all such studies found lowered abundance among macro-moth larvae or adults after treatment, whether comparing *Btk*-treated blocks with controls (Miller 1990a, b, Wagner et al. 1996, Sample et al. 1996) or pretreatment levels with posttreatment levels (Crawford et al. 1992, 1993; Crawford and Austin 1994). Differences between treatments and controls were evident even when weather or other factors were at work (Sample et al. 1996). Where a series of samples were taken at regular intervals after application of *Btk*, abundance within treatment blocks remained lower than within controls over most of the summer (Miller 1990a, Wagner et al. 1996). Much lower numbers were also evident in

the year after treatment, when univoltine, spring-flying species would first be likely to show any effect from treatment the previous year (Sample 1990a, b; Wagner et al. 1996; Sample et al. 1996; Crawford et al. 1993).

We were not able to determine the statistical significance of the effects we observed. However, the effort we put into identifying all specimens and categorizing them by distributional status and risk to *Btk* will allow us to determine whether some subgroups showed lower patterns of abundance than others. In particular, we plan to look for differences between treatments among the three main risk categories and to determine whether habitat generalists within the higher risk categories recovered in numbers more quickly than habitat specialists.

Benefits of Protecting Natural Areas

We found little evidence that any species was extirpated from the area as the result of the AGM eradication project. In fact, several rare species clearly survived or at least quickly recolonized the *Btk* blocks. Nonetheless, we believe the effort to protect a core group of natural areas through use of Gypchek was well worth the effort: virtually all the sites treated with Gypchek turned out to support large numbers of species considered to be of conservation concern by the Natural Heritage Program. Several rare species collected at Peter's Point were, in fact, either not found anywhere else within the project area, or occurred at that site in significantly larger numbers than elsewhere. In the case of *Hemipachnobia subporphyrea* Walker, the most distinctive moth in the entire region, a population survived on the Gypchek-treated area at MOTSU. The fate of the population originally found in the *Btk*-treated portion of the base, however, remains in doubt.

The patterns of recovery seen a year after treatment also suggest that protection of at least large blocks of high quality habitat may play a significant role in recolonization of depleted areas. The recovery within smaller, more isolated blocks are more equivocal, but the continued low abundances observed in those blocks are at least in agreement with our hypothesis that fragmented habitats are particularly vulnerable due to slow rates of recolonization.

RECOMMENDATIONS

Based on the results of this study, we recommend that key natural areas be protected in any large-scale application of *Btk* or any other insecticide with broad non-target impacts. This protection is especially important in areas where native habitats are restricted in distribution, either naturally as in the case of maritime forests, or due to human-caused habitat fragmentation as in the case of the longleaf pine communities. These decisions need not depend on extensive preproject information: our selection of key tracts to protect was based originally on habitat considerations rather than on macro-moth survey data. The North Carolina Natural Heritage Program has, in fact, adopted this approach in reviewing gypsy moth control projects in areas of the state where the fauna of macro-moths has not yet been surveyed.

CONCLUSIONS

The wealth of information on species presence, distribution, abundance levels, habitat affinities, and potential risk from *Btk* -- all of which would have taken years to obtain without the levels of support provided in this study – can form the basis for recommending more effective protection measures or setting up more meaningful monitoring program if a large-scale eradication program ever again becomes necessary. Even if a large eradication program is never needed, the data collected in this study will still be of great use in determining protection priorities and guiding land management decisions within one of the most critical conservation areas in the southeastern United States. In the end, this may be the most important application of what we regard as a model collaborative effort.

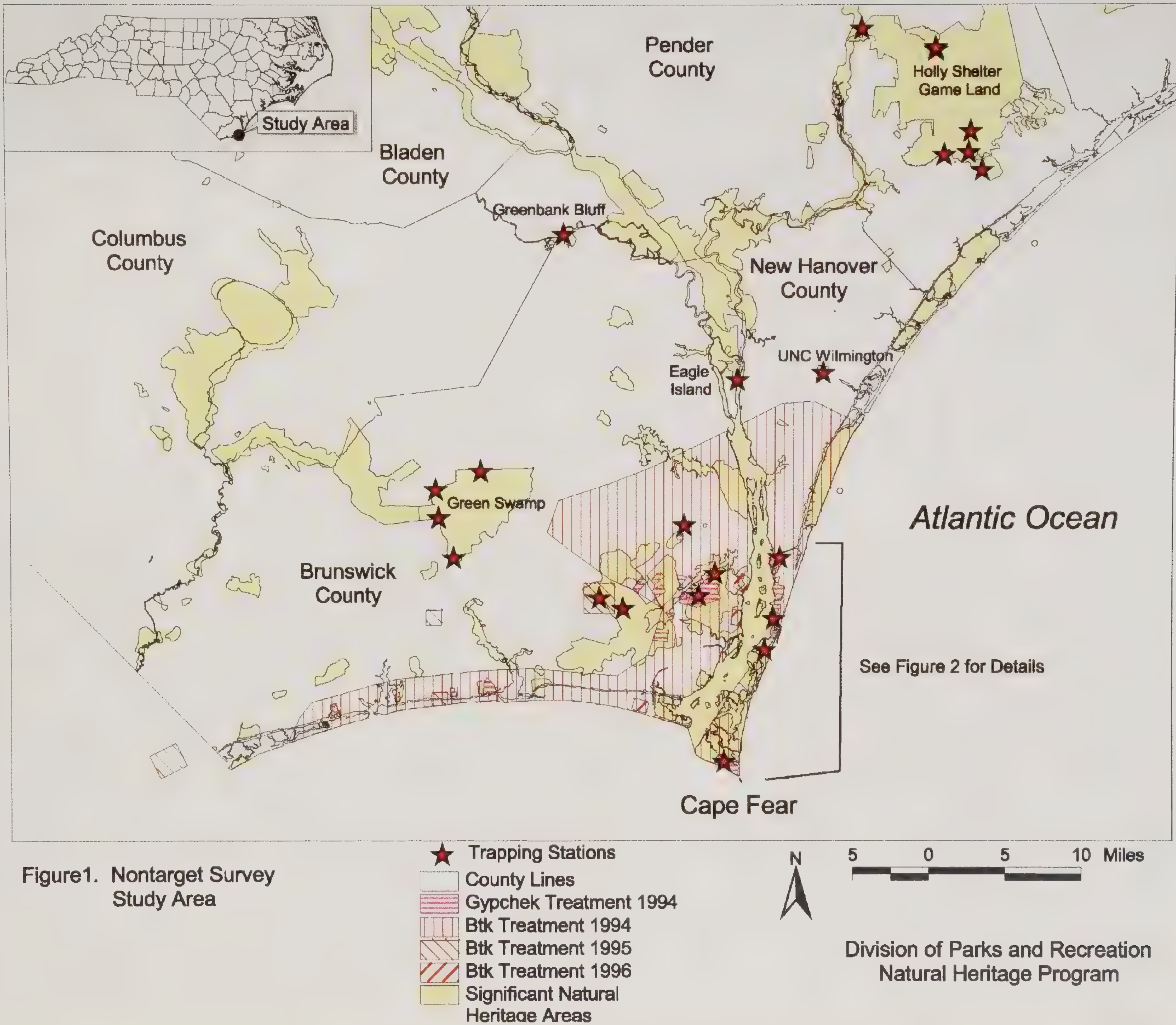


Figure1. Nontarget Survey Study Area

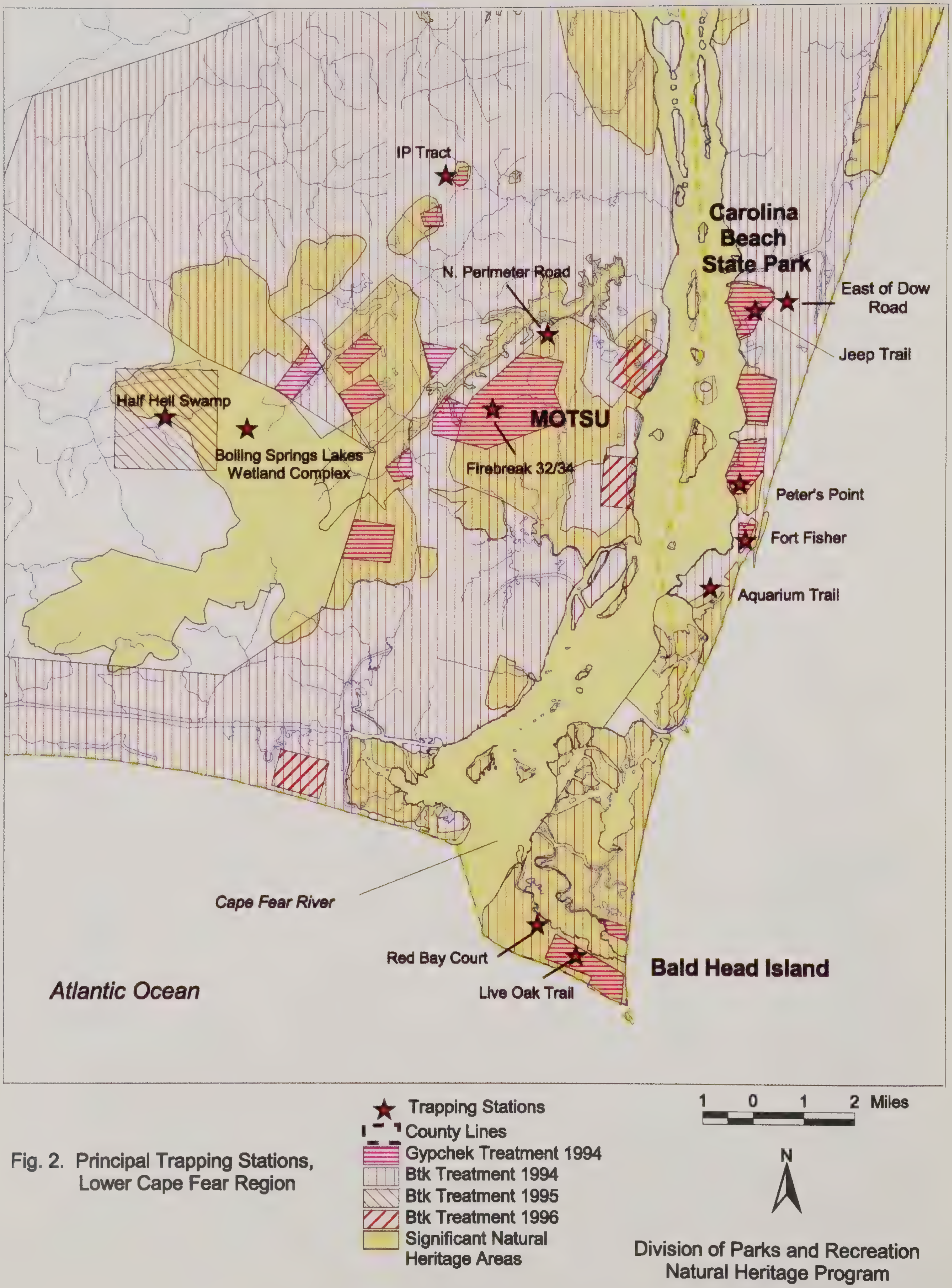


Fig. 2. Principal Trapping Stations, Lower Cape Fear Region

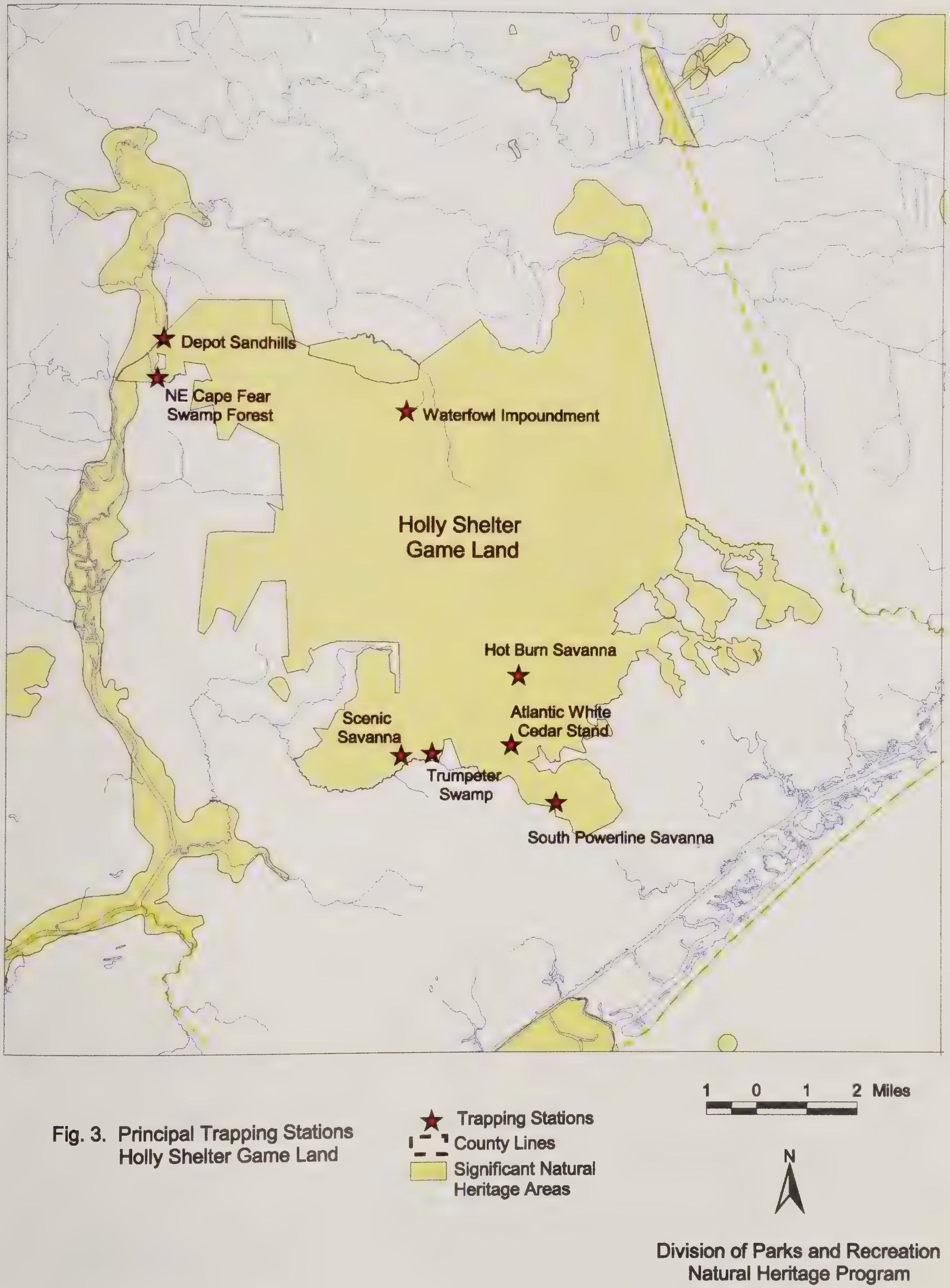
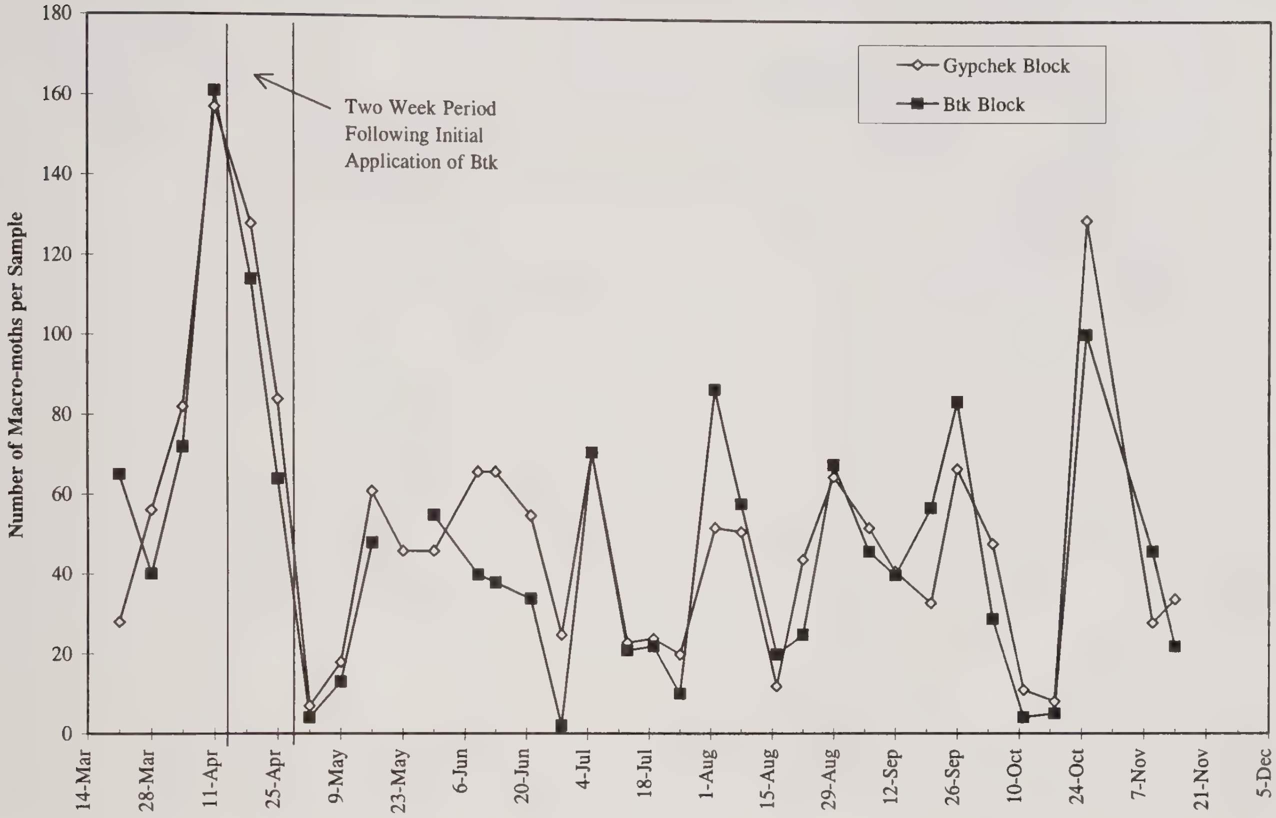


Fig. 3. Principal Trapping Stations
Holly Shelter Game Land

Fig. 4. Principal Trapping Stations, Green Swamp

Figure 5. Weekly Changes in Macro-moth Abundance, MOTSU

a. 1994 Data



b. 1995 Data

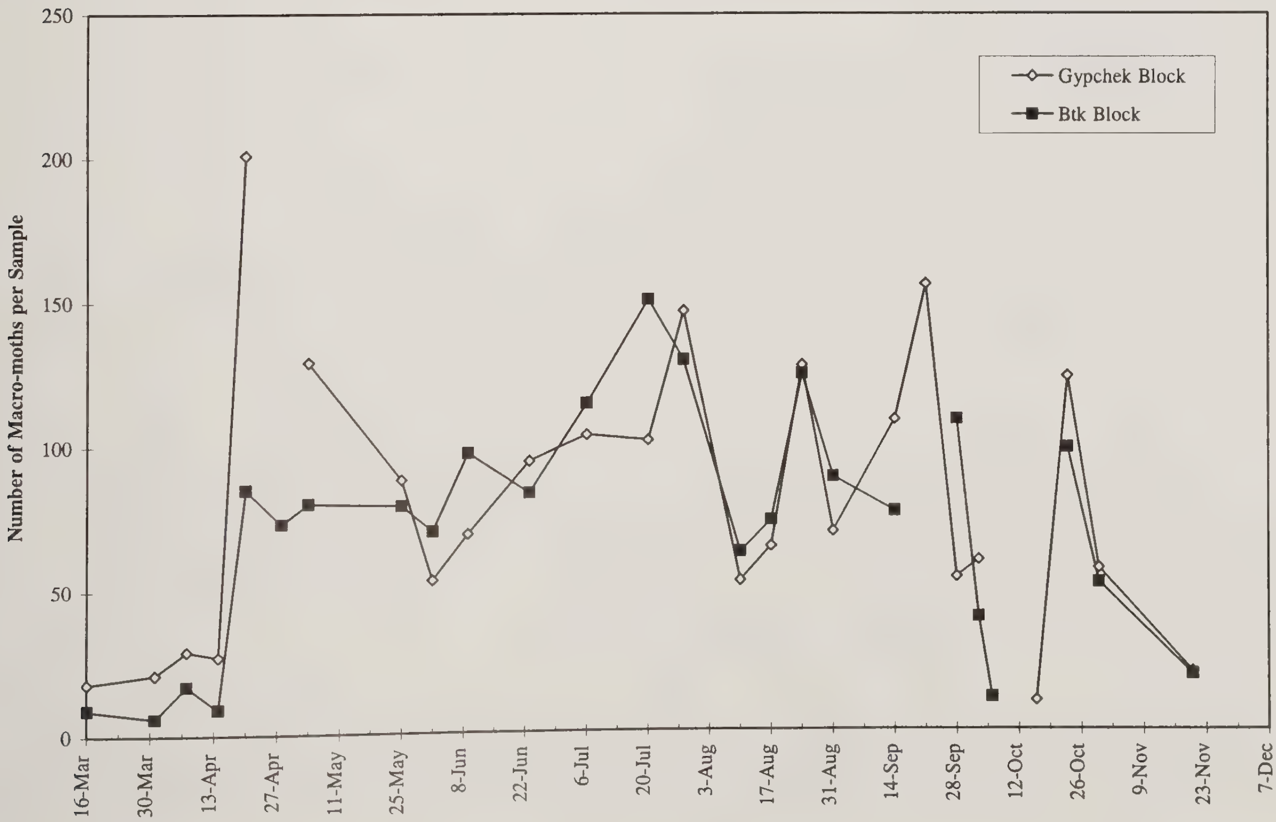
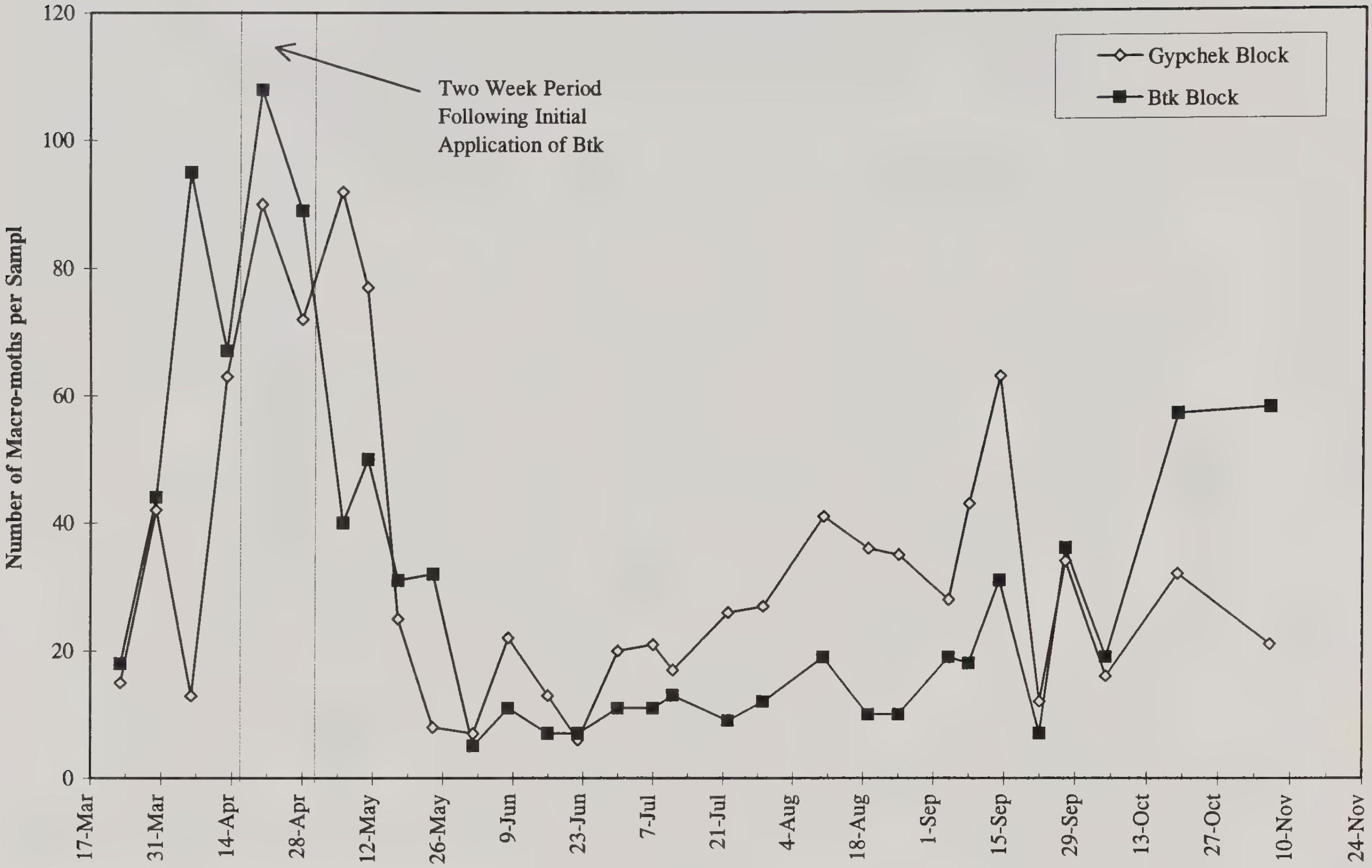


Figure 6. Weekly Changes in Macro-moth Abundance, Carolina Beach State Park

a. 1994 Data



b. 1995 Data

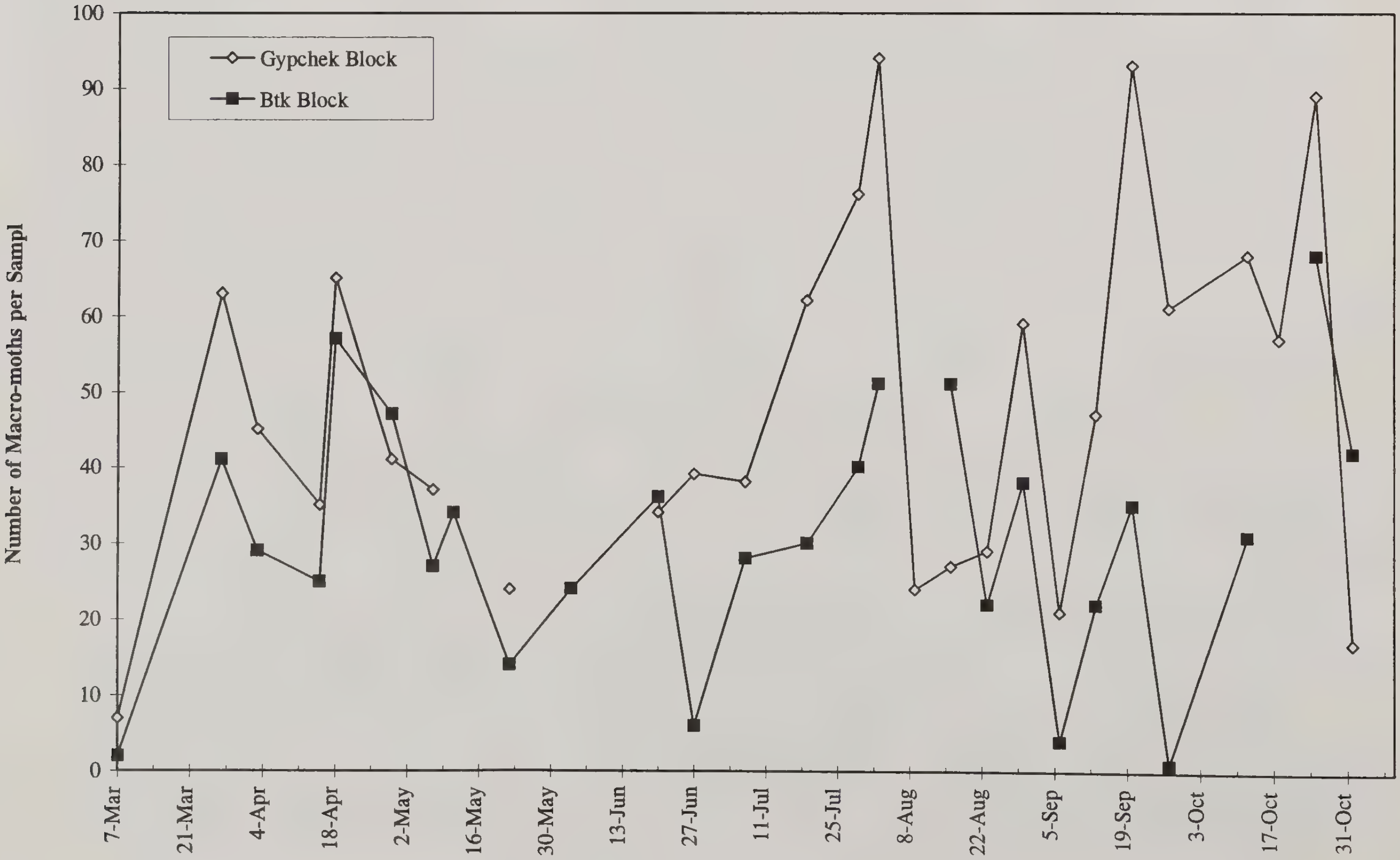
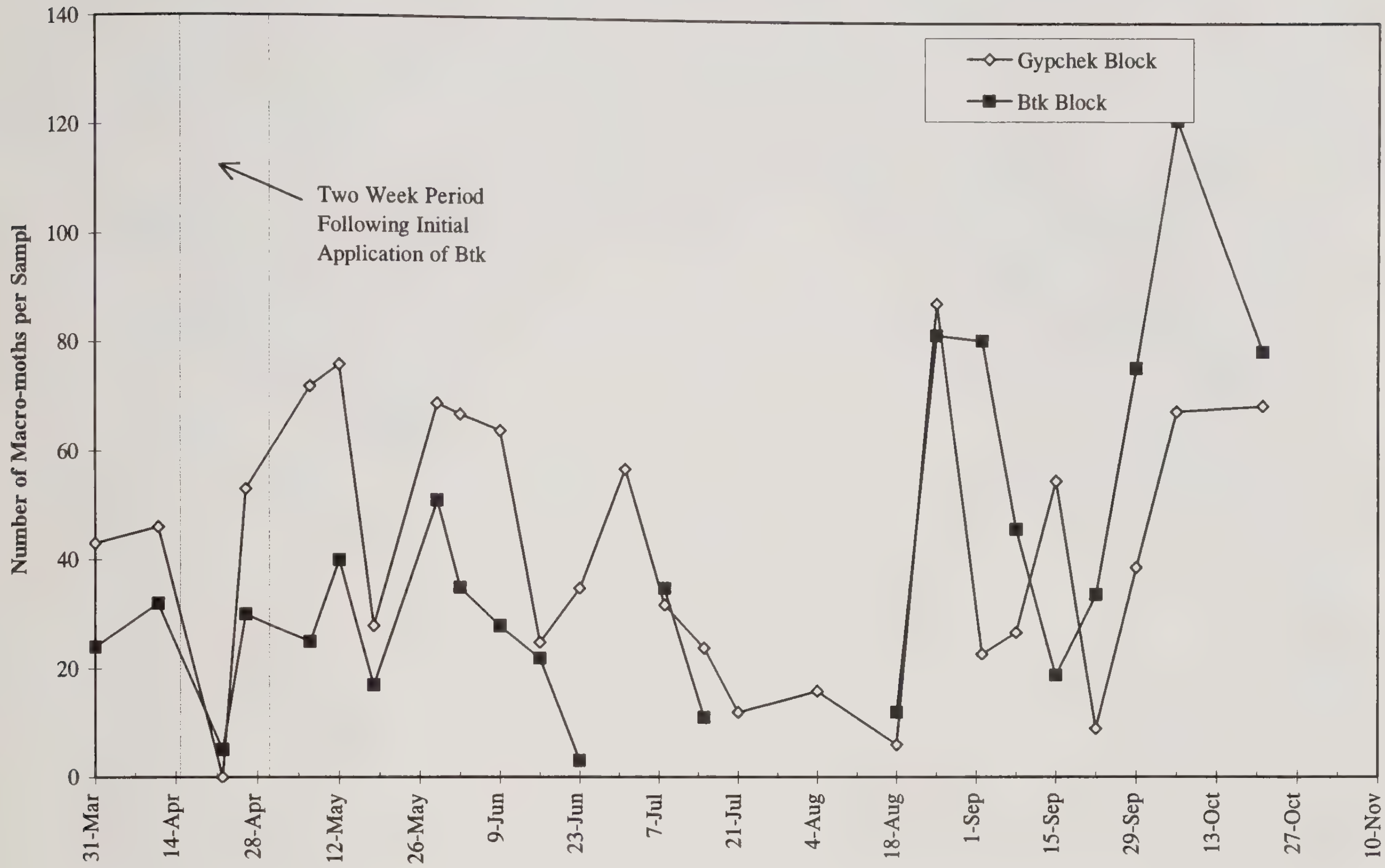


Figure 7. Weekly Changes in Macro-moth Abundance, Bald Head Island

a. 1994 Data



b. 1995 Data

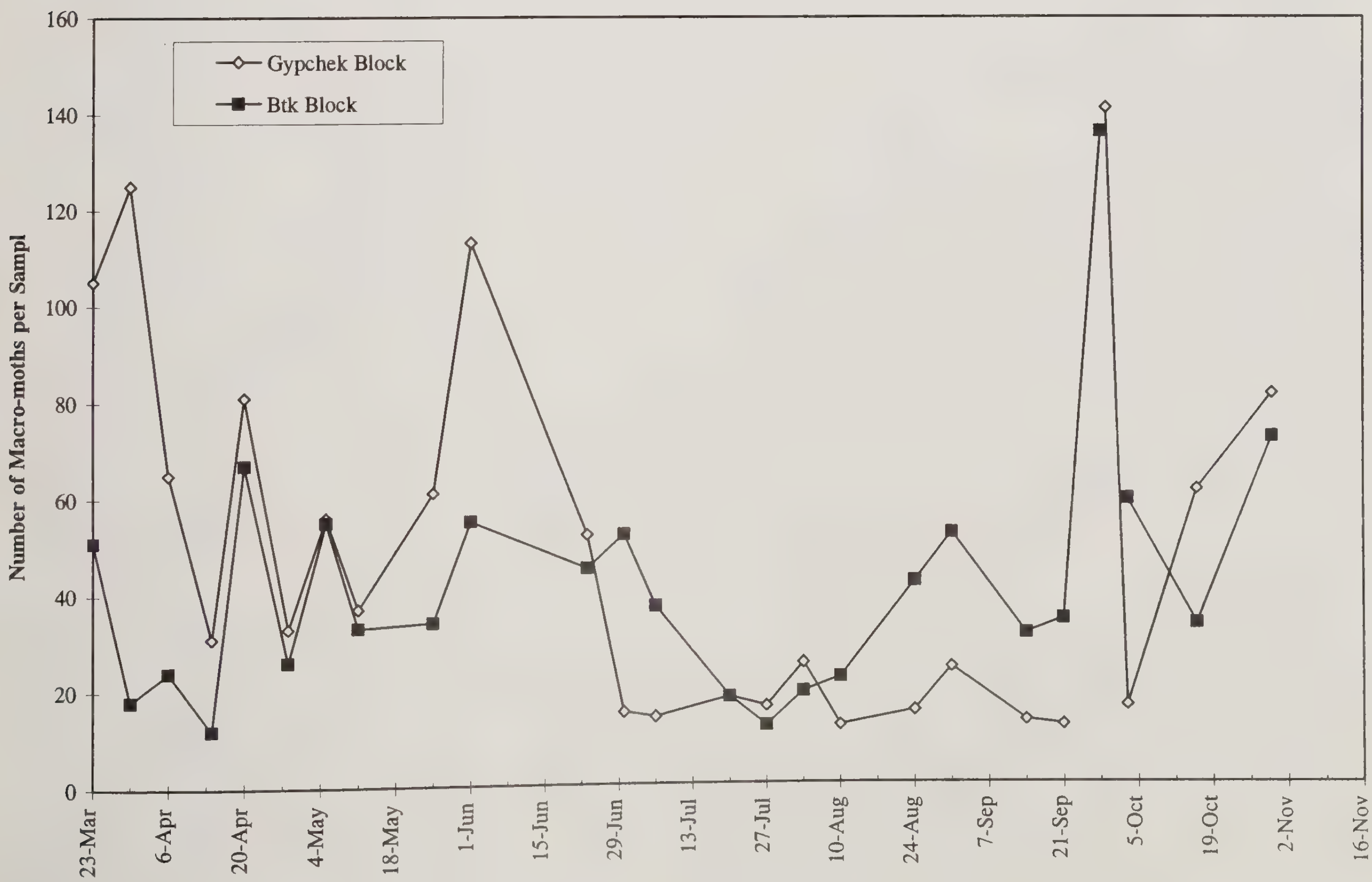


Figure 8. Comparison of MOTSU Abundance Data to 1991 Samples from TNC Savanna Survey

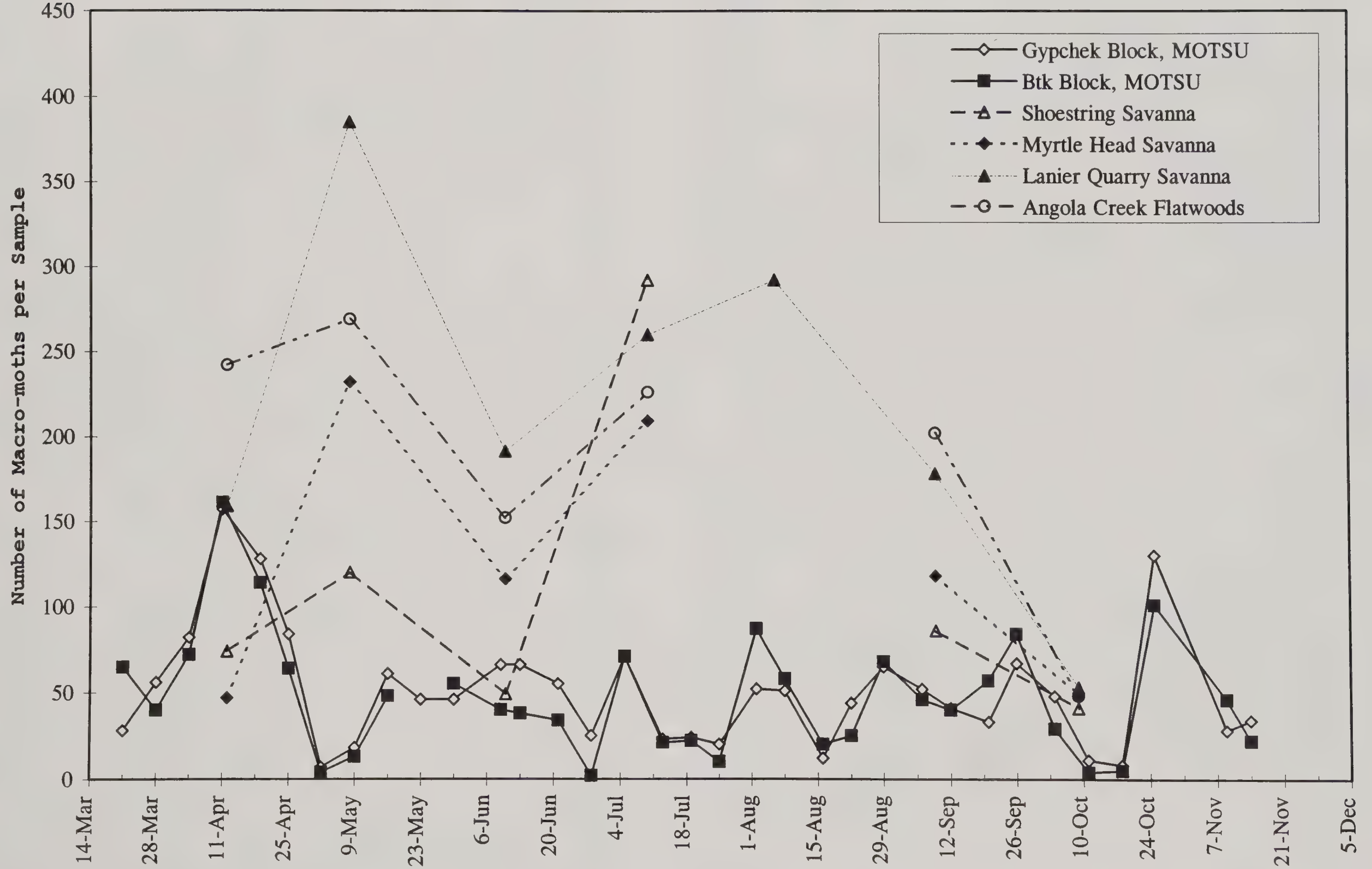


Figure 9. Weekly Changes in Macro-moth Abundance, MOTSU and Boiling Spring Lakes Wetlands, 1994

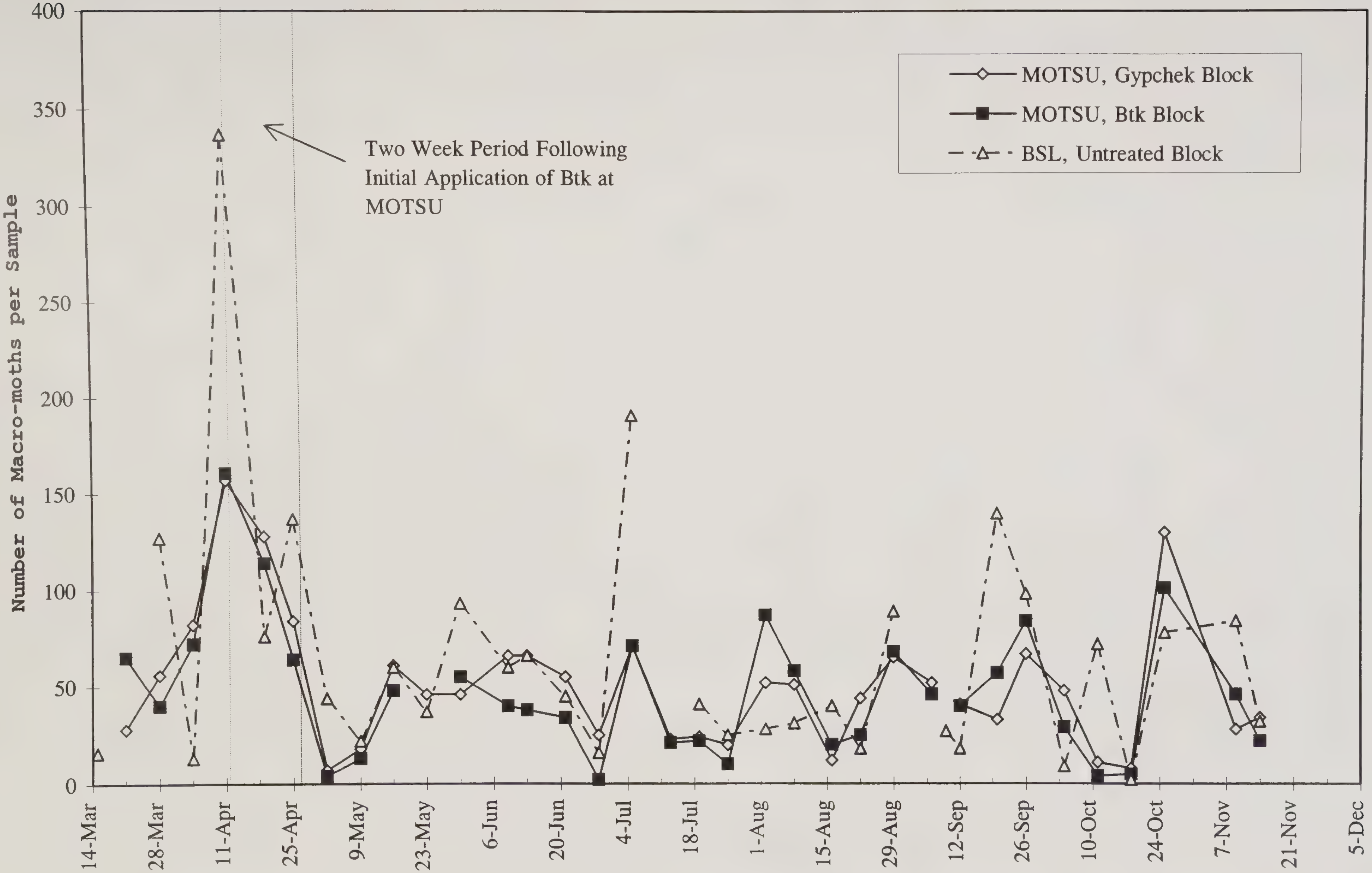


Figure 10. Mean Monthly Precipitation
Brunswick County

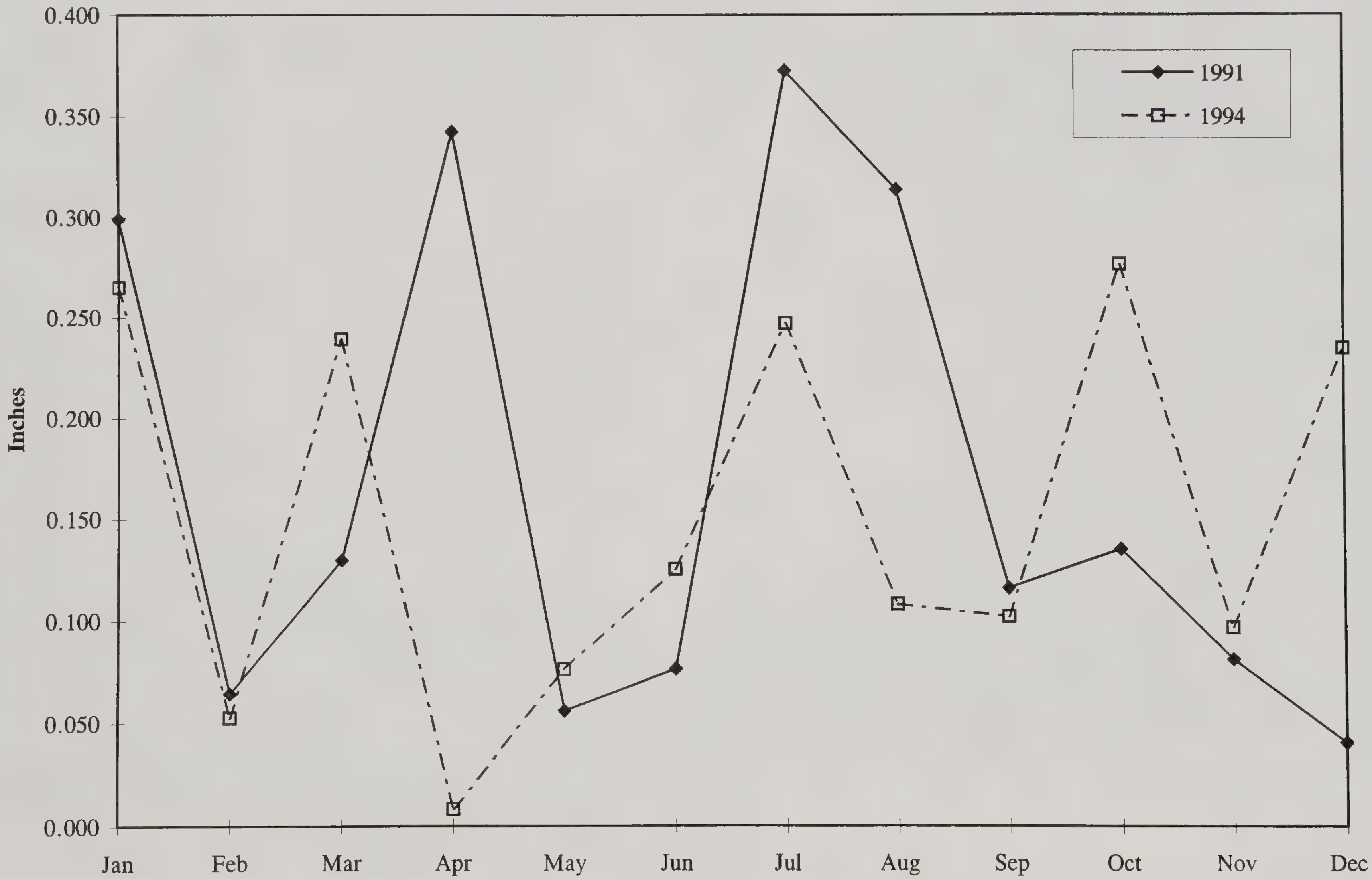


Figure 11. Monthly Mean Temperatures
Brunswick County

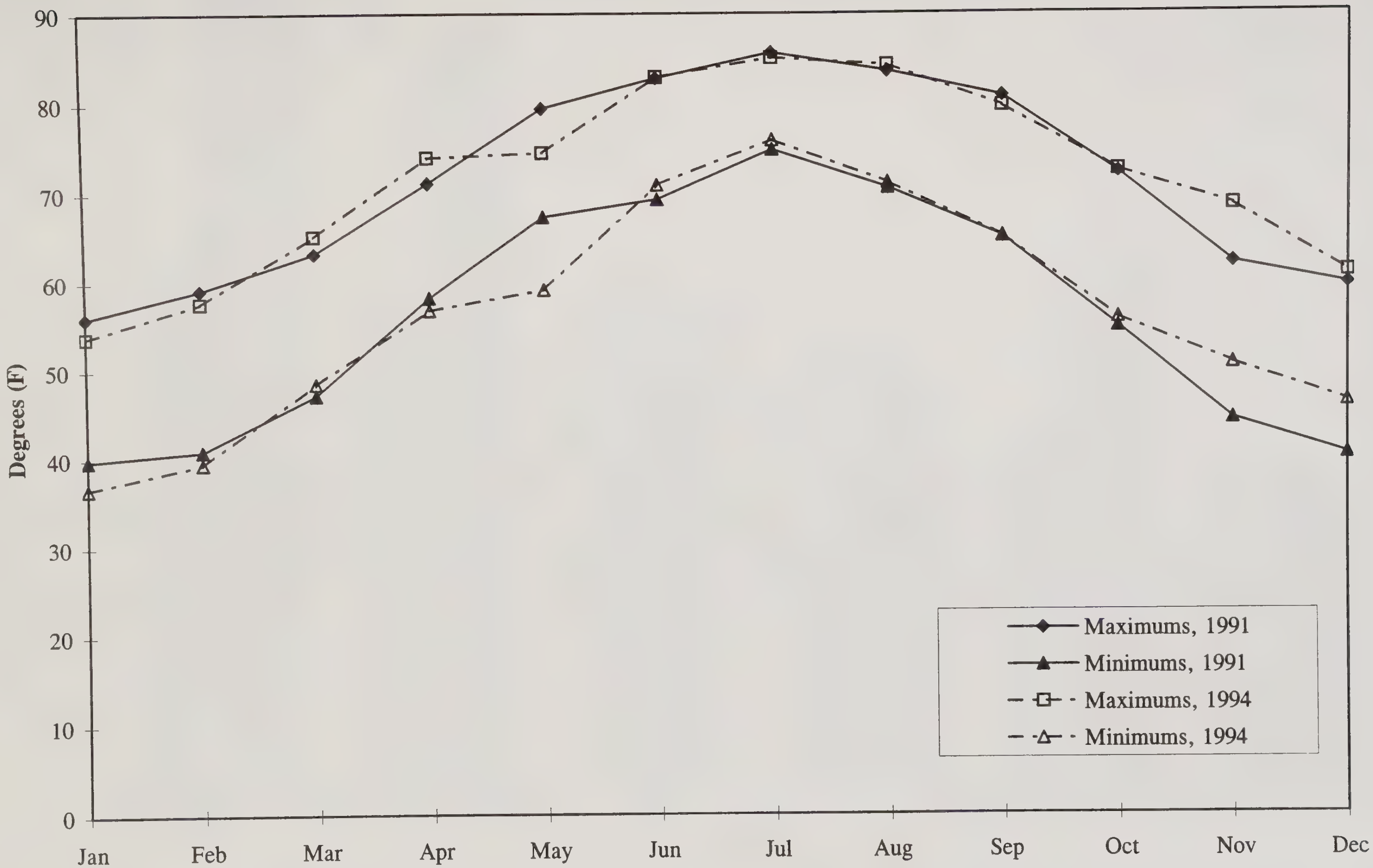


Figure 12. Daily Minimum Temperatures, April - June, Brunswick County 1991 and 1994

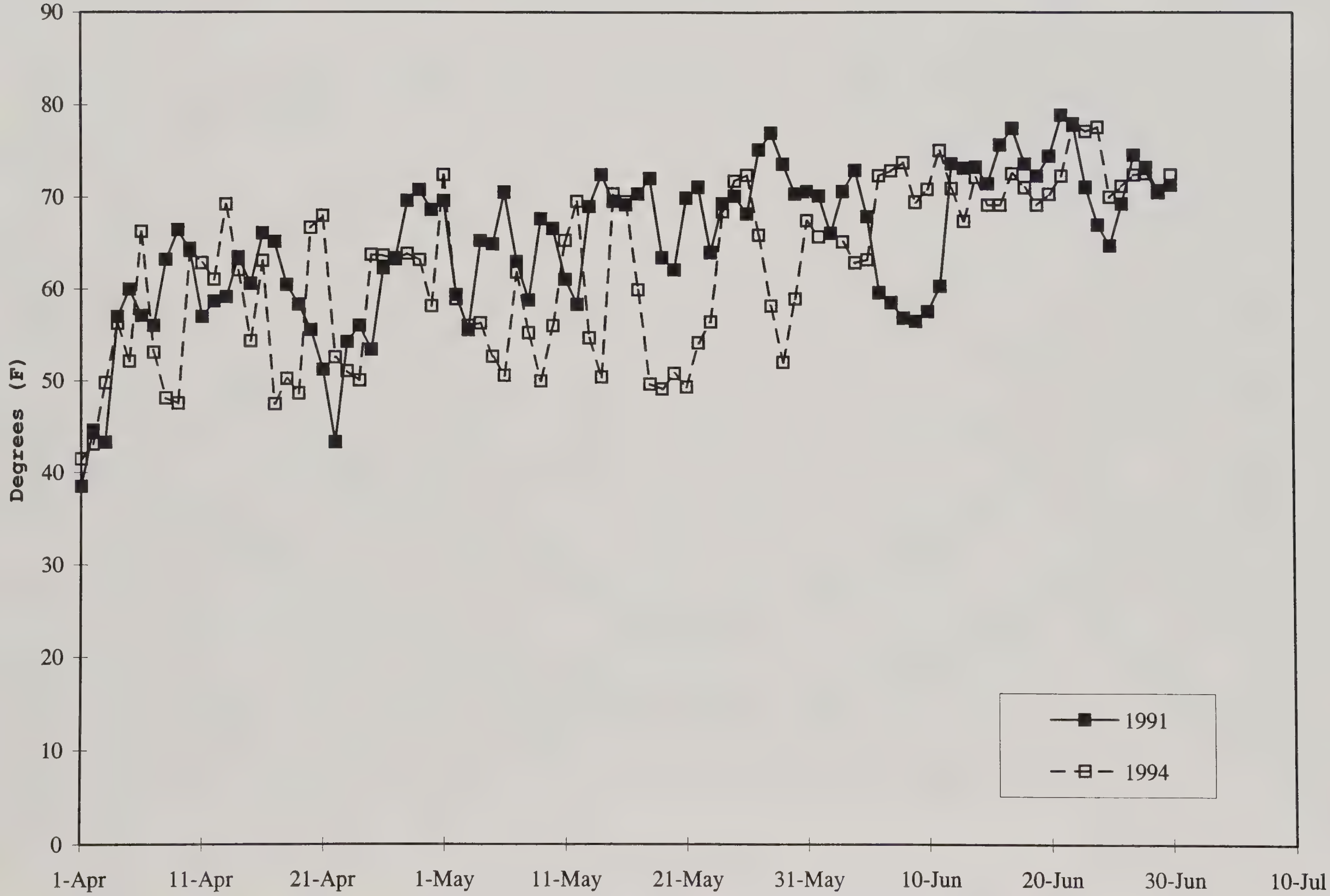
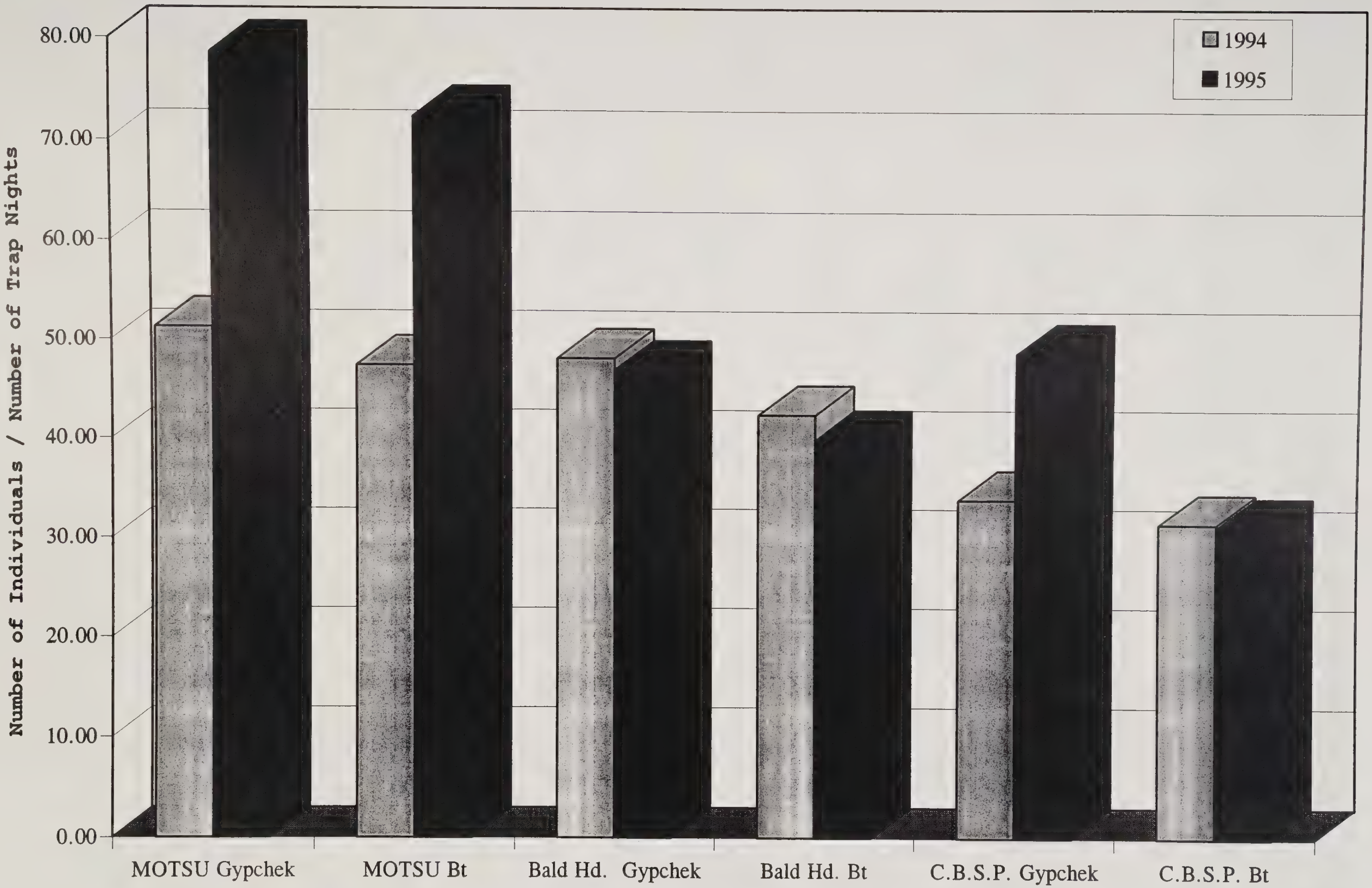


Figure 13. Pooled Abundance Data for 1994 and 1995



APPENDIX A: Description of Trapping Stations and Trapping Summary

TRAPPING STATION (TREATMENT)	HABITATS[1]	NUMBER OF TRAP NIGHTS	NUMBER OF INDIVIDUALS[2]
MOTSU, Firebreak 32/34 (Gypchek - 1994)	Wet Pine Flatwoods, Sand Myrtle Variant	60	3657
MOTSU, N. Perimeter Road (*Btk* - 1994)	Wet Pine Flatwoods, Sand Myrtle Variant	58	3245
Boiling Springs Lakes, IP Tract (*Btk* - 1994)	Slash Pine Plantation/ Wet Pine Flatwoods, Sand Myrtle Variant; Vernal Pool	51	3850
Boiling Springs Lakes, Half Hell Swamp (*Btk* - 1995)	Coastal Plain Small Stream Swamp Forest, Wet Pine Flatwoods, Sand Myrtle variant	35	2579
Boiling Springs Lakes Wetland Complex (Untreated)	Wet Pine Flatwoods, Sand Myrtle Variant; Pine Savanna, Rush Featherling Variant	71	4897
Carolina Beach State Park, East of Dow Road (*Btk* – 1994)	Coastal Fringe Sandhill; Small Depression Pond	62	1868
Carolina Beach State Park, Main Section (Gypchek - 1994)	Coastal Fringe Sandhill; Small Depression Pond	72	2651
MOTSU Bufferlands, Peter's Point (Gypchek - 1994)	Xeric Sandhill Scrub; Coastal Fringe Sandhill	54	4445
Fort Fisher, State Historic Site (Gypchek - 1994)	Coastal Fringe Evergreen Forest	66	3283
Fort Fisher, Aquarium Trail (*Btk* - 1994)	Salt Scrub	9	394
Bald Head Island, Live Oak Trail (Gyp - 1994)	Maritime Evergreen Forest	50	2326
Bald Head Island, Red Bay Court (*Btk* - 1994)	Maritime Evergreen Forest	50	1958
Holly Shelter, Hot Burn Savanna (Untreated)	Pine Savanna	18	1259
Holly Shelter, Scenic Savanna (Untreated)	Pine Savanna	26	1587
Holly Shelter, South Powerline Savanna and Sandridge (Untreated)	Pine Savanna; Pine-Scrub Oak Sandhill	15	850

Trapping Station (Treatment)	Habitats[1]	Number of Trap Nights	Number of Individuals[2]
Holly Shelter, Ctenium and Parnassia Savannas (Untreated)	Pine Savanna	8	328
Holly Shelter, Atlantic White Cedar Stand (Untreated)	Peatland Atlantic White Cedar Forest; Wet Pine Flatwoods; Coastal Plain Small Stream Swamp	27	2552
Holly Shelter, Trumpeter Swamp (Untreated)	Coastal Plain Small Stream Swamp; Wet Pine Flatwoods	30	4525
Holly Shelter, Northeast Cape Fear Swamp Forest (Untreated)	Cypress-gum Swamp (Blackwater Subtype)	4	453
Holly Shelter, Depot Sandhills (Untreated)	Xeric Sandhill Scrub	5	545
Holly Shelter, Waterfowl Impoundment (Untreated)	Coastal Plain Semipermanent Impoundment	2	63
Holly Shelter, Centipede Trail (Untreated)	Pond Pine Woodland	1	148
Greenbank Bluff (Untreated)	Mesic Mixed Hardwoods; Acidic Cliff; Coastal Plain Small Stream Swamp; Coastal Plain Levee Forest	50	4233
Green Swamp, NC 211 Savannas and Flatwoods (Untreated)	Pine Savanna; Wet Pine Flatwoods	20	1272
Green Swamp, Myers-Clemmons Tract (Untreated)	Slash Pine Plantation; Pine-Scrub Oak Sandhill; Vernal Pool	8	647
Green Swamp, Northern Boundary Road (Untreated)	Peatland Atlantic White Cedar Forest	1	221
Eagle Island (Untreated)	Coastal Plain Levee Forest; Tidal Cypress-gum Swamp; Tidal Freshwater Marsh	18	1539
UNC-Wilmington Longleaf Pine Forest (Untreated)	Xeric Sandhill Scrub; Wet Pine Flatwoods; Vernal Pool	15	199
Supplementary Sites, New Hanover County (Untreated)	Various	15	662
Supplementary Sites, Bladen County (Untreated)	Various	11	569

1. Habitat names follow Schafale and Weakley (1990).

2. Totals include macro-moths only.

APPENDIX B: Species Checklist and *Btk* Risk Assessment Summary

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Thyatiridae:						
Pseudothyatira cymatophoroides (6237)	pupa	none				no
Euthyatira pudens (6240)	pupa	full	early			high
Drepanidae:						
Drepana arcuata (6251)	pupa	part	early			mod. to high
Eudeilinia herminiata (6253)						unknown
Oreta rosea (6255)	pupa?	none?				no?
Geometridae:						
Alsophila pometaria (6258)	egg	full	late		high	high
Eumacaria latiferrugata (6272)	pupa?	part	early			mod. to high
Itame pustularia (6273)	egg	full	early			high
Itame varadaria (6314)	egg?	full	early			high
Semiothisa aemulataria (6326)	pupa	part?	early			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Semiothisa promiscuata (6331)	pupa	part?	early?			mod. to high
Semiothisa punctolineata (6332)	pupa	part	early			mod. to high
Semiothisa aequiferaria (6335)	pupa	part	early			mod. to high
Semiothisa distribuaria (6336)	pupa	part	early			mod. to high
Semiothisa transitaria (6339)	pupa	part	early			mod. to high
Semiothisa bicolorata (6341)	pupa	part	early			mod. to high
Semiothisa multilineata (6353)	pupa	part	early			mod. to high
Semiothisa eremiata (6357)	pupa	none				no
Semiothisa ordinata (6358)	pupa	part	early			mod. to high
Semiothisa continuata (6362)	pupa	part	early			mod. to high
Semiothisa gnophosaria (6405)	pupa	none?				no
Hypomecis umbrosaria (6439)	pupa	part	early			mod. to high
Hypomecis gnopharia (6440)	pupa	part	early			mod. to high
Hypomecis longipectinaria (6440.1)	pupa?					unknown
Pimaphera percata (6441)						unknown
Glenoides texanaria (6443)	egg?					unknown

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Glena cribrataria (6449)	pupa	part	early-mid			mod. to high
Glena cognataria (6450)	pupa	full	early-mid			high
Glena plumosaria (6452)	pupa	full	early			high
Exelis pyrolaria (6478)	pupa	none				no
Tornos cinctarius (6485)						unknown
Tornos scolopacinarius (6486)		part?				possible
Tornos abjectarius (6487)						unknown
Anacamptodes cypressaria? (6571)	pupa	none				no
Anacamptodes pergracilis (6580)	pupa	part	early			mod. to high
Anacamptodes vellivolata (6582)	pupa	part	early			mod. to high
Anacamptodes ephyraria (6583)	egg	full	mid?			possible
Anacamptodes humaria (6584)	pupa	part	early-mid			mod. to high
Anacamptodes defectaria (6586)	pupa	part	early-mid			mod. to high
Anavitrinelia pampinaria (6590)	pupa	part	early-mid			mod. to high
Cleora sublunaria (6594)	pupa	full	early-mid			high
Cleora projecta (6595)	pupa	full	early-mid			high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Ectropis crepuscularia (6597)	pupa	part?	early			mod. to high
Protoboarmia porcelaria (6598)	larva	part?	early			mod. to high
Epimecis hortaria (6599)	pupa	part	early-mid			mod. to high
Melanolophia canadaria (6620)	pupa	part	early-mid			mod. to high
Melanolophia signataria (6621)	pupa	full	early-mid			high
Lycia ypsilon (6652)	pupa	full	early-mid			high
Hypagyrtis unipunctata (6654)	larva	part	early			mod. to high
Hypagyrtis esther (6655)	larva	part	early			mod. to high
Hypagyrtis brendae? (6657)	larva	full	mid-late			possible
Phigalia titea (6658)	pupa	full	mid		high	high
Phigalia denticulata (6659)	pupa	full	mid			possible
Phigalia strigataria (6660)	pupa	full?	mid			possible
Paleacrita vernata (6662)	pupa	full	late			possible
Cabera quadrifasciaria (6680)	pupa?	none				no
Erastria cruentaria (6705)	pupa?	part	early			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Thysanopyga intractata (6711)	pupa?	part	early-mid			mod. to high
Episemasia solitaria (6713)	pupa?	part	early-mid			mod. to high
Lytrosis unitaria (6720)	larva	full	late			possible
Lytrosis sinuosa (6721)	larva	full	late			possible
Euchlaena obtusaria (of Field Guide) (6726)	larva	part			none	no
Euchlaena amoenaria (6733)	larva	part	early			mod. to high
Euchlaena "astylusaria" (6733.1)	larva	part	early+late			mod. to high
Euchlaena pectinaria (6735)	larva	part	early			mod. to high
Euchlaena irraria (6739)	larva	part?	late			possible
Xanthotype rufaria (6742)	pupa?	none?				no?
Xanthotype attenuaria (6744)	pupa?	none?				no?
Cymatophora approximaria (6745)	egg?	full	early			high
Stenaspilatodes antidiscaria (6746)	pupa?	full	early			high
Pero zalissaria (6752)	pupa?	part	early			mod. to high
Pero hubneraria (6754)	pupa	full	early			high
Nacophora quernaria (6763)	pupa	full	early-mid			high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Ceratonyx satanaria (6780)	pupa	full	mid?			high
Ennomos magnaria (6797)	egg	full	early		very high	high
Ennomos subsignaria (6798)	egg	full	early			high
Petrophora divisata (6803)	pupa?	part	early			mod. to high
Tacparia zalissaria (6805)	pupa?	part	early			mod. to high
Metarranthis duaria (6822)	pupa	full	early			high
Metarranthis angularia complex (6823)	pupa	none				no
Metarranthis homuraria (6828)	pupa	part?	early			mod. to high
Metarranthis lateritiaria (of Guenee) (6829)	pupa	part	early			mod. to high
Metarranthis n. sp. 1 (6829.1)	pupa	none				no
Metarranthis obfirmaria (6832)	pupa	full	early			high
Cepphis decoloraria? (6834)	pupa?	none?				no?
Probole alienaria (6837)	pupa	part	early			mod. to high
Probole amicaria (6838)	pupa	part?				possible
Plagodis fervidaria (6843)	pupa	part?	early			mod. to high
Caripeta aretaria (6869)	pupa	full	early			high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Besma quercivoraria (6885)	pupa	full	early			high
Lambdina pellucidaria (6892)	pupa	full	early			high
Nepytia n. sp. nr. semiclusaria (6908.1)	egg?	full	early			high
Eusarca fundaria (6933)	egg	full	early			high
Eusarca confusaria (6941)	egg	full	early			high
Tetracis crocallata (6963)	pupa	none?				no?
Eutralepa clemataria (6966)	pupa	full	early		very high	high
Patalene olyzonaria puber (6974.01)	egg?	part	early			mod. to high
Prochoerodes transversata (6982)	egg	full?	early?		high	high?
Nematocampa resistaria (7010)	egg	full	early-mid			high
Nematocampa baggetaria (7011.1)	egg?	part?	early			mod. to high
Nemoria elfa (7029)	pupa?	part?	early			mod. to high
Nemoria lixaria (7033)	larva	part	late			possible
Nemoria saturiba (7034)	pupa?	full	early			high
Nemoria bifilata bifilata (7045.01)	pupa	full	early			high
Nemoria bistriaria bistriaria (7046.01)	pupa	full	early			high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Dichorda iridaria iridaria (7053.01)	pupa	part	early			mod. to high
Synchlora aerata aerata (7058.01)	pupa	full	early			high
Synchlora frondaria frondaria (7059.01)	pupa	none				no
Chlorochlamys chloroleucaria (7071)	pupa?	part	early			mod. to high
Chloropteryx tepperaria (7075)						unknown
Hethemia pistasciaria pistasciaria (7084.01)	pupa	full	early			high
Lobocleta ossularia (7094)		part	early			mod. to high
Lobocleta plemyraria (7097)						unknown
Lobocleta peralbata (7100)						unknown
Idaea demissaria (7114)						unknown
Idaea eremiata (of Forbes) (7115)						unknown
Idaea violacearia (7120)						unknown
Idaea ostentaria (7121)						unknown
Idaea tacturata (7122)						unknown
Idaea obfusaria (7123)	larva					unknown
Pleuroprucha insulsaria (7132)		full	early			high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Cyclophora culicaria (7134)	pupa	full	early			high
Cyclophora packardi (7136)	pupa	part	early			mod. to high
Cyclophora myrtaria (7137)	pupa	part?	early			mod. to high
Cyclophora pendulinaria (7139)	pupa					unknown
Scopula aemulata (7151)						unknown
Scopula cacuminaria (7157)						unknown
Scopula purata (7158)	larva?	full?	mid-late			possible
Scopula limboundata (7159)	larva	full	mid-late			possible
Scopula ordinata (7161)						unknown
Scopula inductata (7169)	larva?	full	mid-late			possible
Leptostales pannaria (7173)						unknown
Leptostales laevitaria (7177)						unknown
Lophosis labeculata (7181)		none				no
Eulithis diversilineata (7196)	pupa	none				no
Eulithis gracilineata (7197)	pupa	none				no
Ecliptopera atricolorata (7214)						unknown

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Hydriomena divisaria (7235)	pupa	full	early			high
Hydriomena transfigurata (7237)	pupa	full	early			high
Hydriomena pluviata (7239)	pupa	full	early-mid			high
Hydria prunivorata (7292)	pupa	part	early			mod. to high
Anticlea multiferata (7330)	pupa?	full	early			high
Xanthorhoe lacustrata (7390)	pupa?					unknown
Orthonama obstipata (7414)	pupa?	none?				no?
Orthonama centrostrigaria (7416)	pupa?	full	early			high
Disclisioprocta stellata (7417)	migr	none				no
Eubaphe mendica (7440)	pupa	none				no
Eubaphe meridiana (7441)	pupa?	none				no
Eupithecia peckorum (7453)		full	early-mid			high
Eupithecia miserulata (7474)		part	early			mod. to high
Eupithecia jejunata (7486)	pupa	full	early-mid			high
Eupithecia matheri (7509.1)	pupa	full	early-mid			high
Eupithecia swettii (7530)		full	early			high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Heterophleps triguttaria (7647)		none?				no?
Dyspteris abortivaria (7648)		full	early			high
Mimallonidae:						
Lacosoma chiridota (7659)	larva	full	early			high
Cicinnus melsheimeri (7662)	larva	full	late			possible
Apatelodidae:						
Apatelodes torrefacta (7663)	pupa	none				no
Olceclostera angelica (7665)	pupa	none				no
Lasiocampidae:						
Tolype velleda (7670)	egg	full	early			high
Tolype notialis (7674)	egg?	full	early			high
Tolype minta (7675)	egg?	full	early			high
Artace cribraria (7683)	egg	full	early			high
Phyllodesma americana (7687)	pupa	full	early			high
Malacosoma disstria (7698)	egg	full	late		very high	high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Malacosoma americanum (7701)	egg	full	late			possible
Saturniidae:						
Eacles imperialis (7704)	pupa	none				no
Citheronia regalis (7706)	pupa	none				no
Citheronia sepulchralis (7708)	pupa	none				no
Dryocampa rubicunda (7715)	pupa	part	early			mod. to high
Anisota stigma (7716)	pupa	none				no
Anisota pellucida (7723.1)	pupa	none				no
Automeris io (7746)	pupa	none				no
Antheraea polyphemus (7757)	pupa	part	early		very high	mod. to high
Actias luna (7758)	pupa	part	early		Very high	mod. to high
Callosamia angulifera (7765)	pupa	none				no
Callosamia securifera (7766)	pupa	part?	early			mod. to high
Sphingidae:						
Hyalophora cecropia (7767)	pupa	part	early			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Agrius cingulata (7771)	migr	none				no
Manduca sexta (7775)	pupa?	none				no
Manduca quinquemaculata (7776)	pupa?	none				no
Manduca rustica (7778)	pupa?	none				no
Manduca jasminearum (7783)	pupa	none				no
Dolba hyloeus (7784)	pupa	part	early			mod. to high
Ceratomia undulosa (7787)	pupa	none				no
Isoparce cupressi (7791)	pupa	part	early			mod. to high
Paratrea plebeja (7793)	pupa	none				no
Sphinx gordius (7810)	pupa	full	early			high
Lapara coniferarum (7816)	pupa	part	early			mod. to high
Smerinthus jamaicensis (7821)	pupa	none				no
Paonias excaecatus (7824)	pupa	none				no
Paonias myops (7825)	pupa	none				no
Paonias astylus (7826)	pupa	none				no
Laothe juglandis (7827)	pupa	part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Enyo lugubris (7851)	migr	none				no
Eumorpha pandora (7859)	pupa	none				no
Eumorpha fasciata (7865)	pupa+migr?	none				no
Deidamia inscripta (7871)	pupa	full	early			high
Darapsa myron (7885)	pupa	part	early			mod. to high
Darapsa pholus (7886)	pupa	part?				possible
Xylophanes tersa (7890)	migr?	none				no
Hyles lineata (7894)	migr	none				no
Notodontidae:						
Clostera inclusa (7896)	pupa	part	early			mod. to high
Datana ministra (7902)	pupa	none				no
Datana angusii (7903)	pupa	none				no
Datana major (7905)	pupa	none				no
Datana contracta (7906)	pupa	none				no
Datana integerrima (7907)	pupa	none				no
Datana perspicua (7908)	pupa	none				no

SPECIES (Moths of North America Checklist No.)	**OVER WINTERING STAGE**[1]	**ESTIMATED LARVAL EXPOSURE**[2]	**PROBABLE INSTARS EXPOSED**[3]	**BORER/ INTERNAL FEEDER**	**BTK ASSAY**	**OVERALL POTENTIAL RISK FROM BTK**
Datana ranaeceps (7911)	pupa	part	early			mod. to high
Nadata gibbosa (7915)	pupa	part	early			mod. to high
Hyperaeschra georgica (7917)	pupa	full	early-mid			high
Peridea angulosa (7920)	pupa	part	early			mod. to high
Nerice bidentata (7929)	pupa	none				no
Gluphisia septentrionalis (7931)	pupa	part?	early			mod. to high
Furcula cinerea (7937)	pupa	none	!			no
Symmerista albifrons (7951)	pupa	full	early			high
Dasylophia anguina (7957)	pupa	none				no
Macrurocampa marthesia (7975)	pupa	none				no
Heterocampa astarte (7977)	pupa	part	early			mod. to high
Heterocampa obliqua (7983)	pupa	part	early			mod. to high
Heterocampa subrotata (7985)	pupa	none				no
Heterocampa umbrata (7990)	pupa	part	early			mod. to high
Heterocampa guttivitata (7994)	pupa	part	early			mod. to high
Heterocampa biundata (7995)	pupa	part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Lochmaeus manteo (7998)	pupa	part	early			mod. to high
Lochmaeus bilineata (7999)	pupa	part	early			mod. to high
Schizura ipomoeae (8005)	pupa	part	early			mod. to high
Schizura unicornis (8007)	pupa	part	early			mod. to high
Schizura apicalis (8009)	pupa	none				no
Schizura concinna (8010)	pupa	none				no
Schizura leptinoides (8011)	pupa	none				no
Schizura n. sp. (8011.1)	prepupa	none?				no?
Oligocentria semirufescens (8012)	pupa	none				no
Oligocentria lignicolor (8017)	pupa	part				possible
Hyparpax aurora (8022)	pupa	part	early			mod. to high
Notodontidae, New Genus 1, New Species 1 (8030.1)	pupa?	none?				no?
Arctiidae:						
Crambidia lithosioides (8045)						unknown
Crambidia pallida complex (8045.1)						unknown

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Crambidia n. sp. nr. pallida (dark) (8045.2)						unknown
Crambidia n. sp. nr. pallida (small) (8045.3)						unknown
Crambidia uniformis (8046)						unknown
Crambidia pura (8052)		part	early			mod. to high
Cisthene plumbea (8067)						unknown
Cisthene subjecta (8071)		part				possible
Cisthene packardii (8072)						unknown
Hypoprepia miniata (8089)		full	mid			possible
Hypoprepia fucosa (8090)	larva	full	mid			possible
Clemensia albata (8098)		part	early			mod. to high
Pagara simplex (8099)		full	early-mid			high
Neoplynes eudora (8101)						unknown
Comachara cadburyi (8104)		part	early			mod. to high
Haploa clymene (8107)	larva	full	late			possible
Haploa colona (8108)	larva	full	late			possible
Holomelina laeta (8114)		part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Holomelina opella (8118)	pupa?	part	early			mod. to high
Holomelina aurantiaca (8121)	pupa?	part	early			mod. to high
Holomelina rubicundaria (8122)						unknown
Pyrrharctia isabella (8129)	larva	part	early			mod. to high
Estigmene acrea (8131)	pupa	none				no
Spilosoma congrua (8134)	pupa	part	early			mod. to high
Spilosoma dubia (8136)	pupa	full	early-mid			high
Spilosoma virginica (8137)	pupa	part	early			mod. to high
Hyphantria cunea (8140)	pupa	full	early			high
Apantesis phalerata (8169)	pupa	part	early			mod. to high
Apantesis vittata (8170)	pupa	part	early			mod. to high
Apantesis carlotta (8171.1)	pupa	part	early			mod. to high
Grammia figurata (8188)	larva	part	early			mod. to high
Grammia phyllira (8194)	larva	full	late			possible
Grammia parthenice intermedia (8196.01)	larva	full	mid?			high
Grammia virgo (8197)	larva	full	mid			possible

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Grammia arge (8199)	pupa	part	early			mod. to high
Halysidota tessellaris (8203)	pupa	none				no
Leucanopsis longa (8217)	pupa?					unknown
Cycnia inopinatus (8228)	pupa	none				no
Euchaetes egle (8238)	pupa	none				no
Pygarctia abdominalis (8255)	pupa	full	early			high
Cisseps fulvicollis (8267)	migr?	part?	early			mod. to high
Lymantriidae:						
Dasychira tephra (8292)	larva	full	mid			possible
Dasychira meridionalis memorata (8298.01)	larva	full	mid			possible
Dasychira atrivenosa (8299)	larva	full	mid			possible
Dasychira leucophaea (8301)	larva	full	mid			possible
Dasychira manto (8307)	larva	full	mid			possible
Orgyia detrita (8313)	egg	full	early			high
Orgyia definita (8314)	egg	full	early			high
Orgyia leucostigma (8316)	egg	full	early			high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Noctuidae:						
Idia americalis (8322)	larva	full	all?			high
Idia aemula (8323)	larva	full	all?			high
Idia rotundalis (8326)	larva	full	mid-late			high
Idia forbesi (8327)	larva	full	mid-late			high
Idia julia (8328)	larva	full	mid-late			high
Idia diminuendis (8329)	larva	full	mid-late			high
Idia lubricalis (8334)	larva	full	mid-late			high
Phalaenophana pyramusalis (8338)		full?	mid?			high
Zanclognatha lituralis (8340)	larva	full	all?			high
Zanclognatha theralis (8341)	larva	full	mid-late			high
Zanclognatha obscuripennis (8347)	larva	full	mid-late			high
Zanclognatha cruralis (8351)	larva	full	mid-late			high
Chytolita morbidalis (8355)	larva	full	mid-late			high
Chytolita petrealis (8356)	larva	full	mid-late			high
Macrochilo hypocritalis (8357.1)	larva?	full?	mid?-late?			possible

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Macrochilo litophora (8358)						unknown
Macrochilo orciferalis (8360)	larva?	full?	mid?-late?			possible
Macrochilo louisiana (8361)	larva?	full?	mid-late?			possible
Macrochilo santerivalis (8361.1)	larva?	full?	mid-late?			possible
Phalaenostola larentioides (8364)	larva	full	late			high
Tetanolita mynesalis (8366)		part	early			high
Tetanolita floridana (8368)		part	early			high
Bleptina caradrinalis (8370)	larva	full	late+early			high
Bleptina inferior (8371)	larva	full	all?			high
Bleptina sangamonia (8372)						unknown
Hypenula cacuminalis (8376)	migr?					unknown
Renia salusalis (8378)	larva	full	mid?			high
Renia nemoralis (8380)	larva	full				high
Renia discoloralis (8381)	larva	full	mid?			high
Renia n. sp. nr. discoloralis (8381.1)	larva	full	mid-late			high
Renia flavipunctalis (8384.1)	larva	full	mid?			high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Renia fraternalis (8385)	larva	full	late+early			high
Renia adspergillus (8386)	larva	full	all?			high
Renia sobrialis (8387)	larva	full	mid?			high
Lascoria ambigualis (8393)		part	early			high
Palthis angulalis (8397)		full	early			high
Palthis asopialis (8398)		part	early			mod. to high
Redectis pygmaea (8400)						unknown
Redectis vitrea (8401)						unknown
Rivula propinqualis (8404)						unknown
Oxycilla mitographa (8408)						unknown
Colobochyla interpuncta (8411)		full	early			high
Hypenodes fractilinea (8421)						unknown
Dyspyralis nigella (8428)						unknown
Dyspyralis n. sp. (8429.1)						unknown
Schrankia macula (8431)						unknown
Ablemma brimleyana (8437)						unknown

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Nigetia formosalis (8440)						unknown
Bomolocha manalis (8441)	pupa	part	early			mod. to high
Bomolocha baltimoralis (8442)	pupa	none?				no?
Bomolocha bijugalis (8443)	pupa	none				no
Bomolocha palparia (8444)	pupa	none				no
Ophiuche degasalis (8459)	migr	none				no
Plathypena scabra (8465)	adult	full	early			high
Hemeroplanis scopulepes (8467)	pupa?	full	early			high
Hemeroplanis habitalis (8471)	pupa?	part	early			mod. to high
Phytometra rhodarialis (8481)	pupa?	part	early			mod. to high
Hormoschista latipalpis (8488)	pupa?	none?				no?
Pangrapta decoralis (8490)	pupa	part	early			mod. to high
Ledaea perditalis (8491)						unknown
Metalectra discalis (8499)		full	early			high
Metalectra quadrisignata (8500)		none?				no?
Metalectra tantillus (8502)		part	early			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Metalectra albilinea (8504)	pupa?					unknown
Metalectra richardsi (8505)		none				no
Arugisa latiorella (8509)	larva	full	mid-late			possible
Scolecocampa liburna (8514)		none		yes		no
Gabara subnivosella bipuncta (8522.01)						unknown
Gabara distema humeralis (8523.01)						unknown
Gabara pulverosalis (8524)						unknown
Gabara n. sp. (8524.1)						unknown
Phyprosopus callitrichoides (8525)	pupa?	part	early			mod. to high
Hypsoropha monilis (8527)	prepupa	part	all?			mod. to high
Hypsoropha hormos (8528)	prepupa	none				no
Plusiodonta compressipalpis (8534)	pupa	part	early			mod. to high
Scoliopteryx libatrix (8555)	adult	full	early			high
Litoprosopus futilis (8556)						unknown
Dipthera festiva (8560)						unknown
Metallata absumens (8573)	migr?	none				no

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Anticarsia gemmatilis (8574)	migr	none				no
Panopoda rufimargo (8587)	pupa	none				no
Panopoda carneicosta (8588)	pupa	none				no
Panopoda repanda (8589)	pupa	part	early			mod. to high
Phoberia atomaris (8591)	pupa	full	early			high
Phoberia orthosioides (of Ferguson) (8591.1)	pupa	full	early			high
Cissusa spadix (8592)	pupa	full	early			high
Melipotis jucunda (8607)	pupa	part	early			mod. to high
Drasteria graphica (8618)	pupa	full	early			high
Synedoida grandirena (8641)	pupa	full	early			high
Lesmone detrahens (8651)	pupa	none?				no?
Metria amella (8666)	pupa	part	early			mod. to high
Pseudanthracia coracias (8683)	pupa	part	early			mod. to high
Zale lunata (8689)	pupa	full	early			high
Zale declarans (8691)	pupa	part	early			mod. to high
Zale galbanata (8692)	pupa	part?	early?			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Zale aeruginosa (8694)	pupa	part	early		unclear	mod. to high
Zale minerea (8697)	pupa	part	early			mod. to high
Zale phaeocapna (8698)	pupa	full	early-mid			high
Zale obliqua (of Forbes) (8699)	pupa	none				no
Zale n. sp. nr. obliqua (8699.1)	pupa	full	early			high
Zale squamularis (8700)	pupa	full	early			high
Zale helata (8704)	pupa	full?	early			high?
Zale buchholzi (8706)	pupa	full	early			high
Zale n. sp. nr. buchholzi (8706.1)	pupa	none				no
Zale lunifera (8713)	pupa	full	mid-late			possible
Zale calycanthata (8714)	pupa	full	early			high
Zale horrida (8717)	pupa	full	early			high
Allotria elonympha (8721)	pupa	part	early			mod. to high
Ophisma tropicalis (8722)	migr?	none				no
Dysgonia similis (8725)	pupa	part to full	early			mod. to high
Dysgonia smithii (8726)	pupa?	part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	**OVER WINTERING STAGE**[1]	**ESTIMATED LARVAL EXPOSURE**[2]	**PROBABLE INSTARS EXPOSED**[3]	**BORER/ INTERNAL FEEDER**	**BTK ASSAY**	**OVERALL POTENTIAL RISK FROM BTK**
Parallelia bistriaris (8727)	pupa	none				no
Cutina albopunctella (8728)						unknown
Cutina distincta (8729)						unknown
Cutina aluticolor (8729.1)						unknown
Cutina arcuata (8729.2)						unknown
Euclidia cuspidea (8731)	pupa	part	early			mod. to high
Caenurgia chloropha (8733)	pupa	part	early-mid			mod. to high
Caenurgina crassiuscula (8738)	pupa	full	early			high
Caenurgina erechtea (8739)	pupa	full	early			high
Mocis latipes (8743)	migr	none				no
Mocis marcida (8744)	migr?	none?				no?
Mocis texana (8745)	pupa	part				possible
Celiptera frustulum (8747)	pupa	none				no
Ptichodis herbarium (8750)	pupa?	part	early-mid			mod. to high
Ptichodis bistrigata (8751)	pupa?	full	early-mid			high
Argyrostrotis flavistriaria (8759)	pupa?	part	early-mid			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Argyrostrotis sylvarum (8760)	pupa?	part	early-mid			mod. to high
Argyrostrotis erasa (8761)	pupa?	part	early-mid			mod. to high
Argyrostrotis quadrifilaris (8762)	pupa?	full?	early			high?
Argyrostrotis deleta (8763)	pupa?	part	early-mid			mod. to high
Doryodes bistrialis (8765)	pupa	part	early-mid			mod. to high
Doryodes spadaria (8767)	pupa	part to full	early			mod. to high
Doryodes n. sp. (8768.1)	pupa	part to full	early			mod. to high
Catocala piatrix (8771)	egg	part	early			mod. to high
Catocala muliercula (8774)	egg	part	early			mod. to high
Catocala vidua (8792)	egg	full	early		very high	high
Catocala lacrymosa (8794)	egg	full	early			high
Catocala ilia (8801)	egg	full	mid		very high	high
Catocala marmorata (8804)	egg		early?			unknown
Catocala amatrix (8834)	egg	part	early			mod. to high
Catocala amestris (8844)	egg	full	mid-late			possible
Catocala messalina (8845)	egg	full	mid			possible

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Catocala sordida (8846)	egg	full	mid		low	high
Catocala gracilis (8847)	egg	full	mid			possible
Catocala andromedae (8849)	egg	full	mid		low	high
Catocala ultronia (8857)	egg	part	early			mod. to high
Catocala lincolnana (8860)	egg	full	mid-late			possible
Catocala praeclara (8865)	egg	full	mid-late		moderate	high
Catocala clintoni (8872)	egg	full	late			possible
Catocala similis (8873)	egg	full	mid-late		low	high
Catocala micronympha (8876)	egg	full	mid-late			possible
Catocala amica (8878)	egg	full	early-mid			high
Catocala lineella (8878.1)	egg	full	early-mid		very high	high
Catocala n. sp. nr. amica (8878.2)	egg	full	early-mid			high
Catocala jair (8879)	egg	full	early-mid			high
Argyrogramma verruca (8885)	migr?	none				no
Enigmogramma basigera (8886)	migr?	none				no
Trichoplusia ni (8887)	migr?	none				no

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Ctenoplusia oxygramma (8889)	migr	none				no
Pseudoplusia includens (8890)	migr	none				no
Exyra fax (8905.1)	larva	full	mid-late	yes		no
Exyra ridingsii (8905.2)	larva	full	mid-late	yes		no
Exyra semicrocea (8905.3)	larva	full	mid-late	yes		no
Megalographa biloba (8907)	larva	full	late			possible
Marathyssa inficita (8955)	pupa	part	early			mod. to high
Marathyssa basalis (8956)	pupa	part	early			mod. to high
Paectes oculatrix (8957)	pupa	none				no
Paectes pygmaea (8959)	pupa	none				no
Paectes abrostoloides (8962)	pupa?	none?				no?
Baileya doubledayi (8969)	pupa	full	early-mid			high
Baileya ophthalmica (8970)	pupa	none?				no?
Baileya levitans (8972)	pupa	full	early			high
Meganola minuscula (8983)	pupa	part	early-mid			mod. to high
Meganola phylla (8983.1)	pupa	part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Nola pustulata (8989)	egg	full	all?			mod. to high
Nola sorghiella (8991)						unknown
Nola triquetrana (8992)	pupa	full	early-mid			high
Nola clethrae (8996)	pupa	part	early-mid			mod. to high
Oruza albocostaliata (9025)						unknown
Ozarba aerea (9030)						unknown
Hyperstrotia pervertens (9037)	pupa	none				no
Hyperstrotia villificans (9038)	pupa	none				no
Hyperstrotia flaviguttata (9039)	pupa	full?				possible
Hyperstrotia secta (9040)	pupa	none				no
Thioptera nigrofimbria (9044)		part	early			mod. to high
Lithacodia bellicula (9046)	pupa?	none				no
Lithacodia muscosula (9047)	pupa?	none				no
Lithacodia musta (9051)	pupa?	none?				no?
Lithacodia n. sp. (9052.1)	pupa?	none?				no?
Pseudostrotia carneola (9053)	pupa?	none?				no?

Species (Moths of North America Checklist No.)	**Over wintering Stage**[1]	**Estimated Larval Exposure**[2]	**Probable Instars Exposed**[3]	**Borer/ Internal Feeder**	**Btk Assay**	**Overall Potential Risk from Btk**
Homophoberia apicosa (9057)						unknown
Cerma cora (9061)	pupa	full	early			high
Cerma cerintha (9062)	pupa	none				no
Leuconycta diptheroides (9065)	egg?					unknown
Amyna octo (9070)	migr	none				no
Eumicremma minima (9076)		full?	early			high?
Tarachidia parvula (9083)	pupa	part	early			mod. to high
Tarachidia semiflava (9085)	pupa	part	early			mod. to high
Tarachidia candefacta (9090)	pupa	part	early			mod. to high
Spragueia onagrus (9126)		full?	early			high?
Spragueia leo (9127)		none				no
Acontia aprica (9136)	pupa	none				no
Acontia terminimaculata (9145)	pupa	none				no
Panthea n. sp. nr. furcilla (9182.1)	pupa	full	early			high
Charadra deridens (9189)	pupa	none				no
Raphia abrupta (9192)	pupa	none				no

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Acronicta americana (9200)	pupa	none				no
Acronicta tritona (9211)	pupa	part	early			mod. to high
Acronicta vinnula (9225)	pupa	part	early			mod. to high
Acronicta laetifica (9227)	pupa	part	early			mod. to high
Acronicta hasta (9229)	pupa	part	early			mod. to high
Acronicta lobeliae (9238)	pupa	part	early			mod. to high
Acronicta exilis (9242)	pupa	none				no
Acronicta modica (9244)	pupa	none				no
Acronicta clarescens (including pruni) (9246)	pupa	none				no
Acronicta inclara complex (9250)	pupa	part?	early			mod. to high
Acronicta retardata (9251)	pupa	part	early			mod. to high
Acronicta afflicta (9254)	pupa	part	early			mod. to high
Acronicta brumosa (9255)	pupa	part?	early			mod. to high
Acronicta impleta (9257)	pupa	full	early-mid			high
Acronicta noctivaga (9259)	pupa	full	early			high
Acronicta longa (9264)	pupa	part	early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Acronicta oblinita (9272)	pupa	part	early			mod. to high
Acronicta lanceolaria (9274)	pupa	full	early			high
Acronicta sinescripta (9274.1)	pupa	none				no
Simyra henrici (9280)	pupa	full?	early			high?
Agriopodes fallax (9281)	pupa	none				no
Polygrammate hebraeicum (9285)	pupa	part	early			mod. to high
Harrisimemna trisignata (9286)	pupa	none?				no?
Cryphia cyanympha (9297.1)						unknown
Eudryas unio (9299)	pupa	none				no
Eudryas grata (9301)	pupa	none				no
Alypia octomaculata (9314)	pupa	part	early			mod. to high
Meropleon cosmion (9425)	egg or larva			yes		no
Meropleon diversicolor sullivani (9427)	egg or larva			yes		no
Spartiniphaga carterae (9436.1)	larva	full	early-mid	yes		no
Archanara oblonga (9449)	egg	full		yes		no
Parapamea buffaloensis (9463)	egg or larva	part?		yes		no

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Papaipema duovata (9465)	egg	part		yes		no
Papaipema stenoscelis (9481)	egg	full		yes		no
Papaipema speciosissima (9482)	egg	full		yes		no
Papaipema marginidens (9492)	egg	part		yes		no
Papaipema appassionata (9493)	egg	full		yes		no
Papaipema eryngii (9494)	egg	part		yes		no
Achatodes zeae (9520)	larva			yes		no
Iodopepla u-album (9522)		full				unknown
Bellura brehmei (9524)	prepupa	none		yes		no
Bellura densa (9526)	prepupa	none		yes		no
Euplexia benesimilis (9545)	pupa?	none?				no?
Phlogophora periculosa (9547)	larva	full	late			possible
Chytonix palliatricula (9556)		part?	late+early			mod. to high
Chytonix sensilis (9557)		full?	mid?			high?
Nedra ramosula (9582)	pupa	part	early			mod. to high
Phosphila turbulenta (9618)	pupa	part?	early			mod. to high

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Phosphila miselioides (9619)	pupa	part	early			mod. to high
Fagitana littera (9629)	pupa?	part	early			mod. to high
Callopistria floridensis (9630)	migr?	none				no
Callopistria mollissima (9631)	pupa?	part	early			mod. to high
Callopistria granitosa (9632)	pupa?	none				no
Callopistria cordata (9633)	pupa?	part	early			mod. to high
Amphipyra pyramidoides (9638)	egg	full	mid-late		high	high
Anorthodes tarda (9650)		part	early			mod. to high
Balsa malana (9662)	pupa	part	early			mod. to high
Balsa tristrigella (9663)	pupa	part to full	early			mod. to high
Balsa labecula (9664)	pupa	part	early			mod. to high
Spodoptera exigua (9665)	migr	none				no
Spodoptera frugiperda (9666)	?+migr					unknown
Spodoptera ornithogalli (9669)	?+migr					unknown
Spodoptera dolichos (9671)	migr	none				no
Spodoptera eridania (9672)	migr	none				no

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Elaphria nucicolora (9676)	pupa?	full?	early			high?
Elaphria versicolor (9678)	pupa?	none?				no?
Elaphria chalcedonia (9679)	pupa?	part?				possible
Elaphria georgei (9680)	pupa?	full	early			high
Elaphria festivoides complex (9681.1)	pupa?	part	early-mid			mod. to high
Elaphria grata (9684)	pupa	full	early			high
Galgula partita (9688)	pupa	part	early			mod. to high
Platysenta videns (9690)	pupa?	part				possible
Platysenta mobilis (9693)	pupa?	part	early			mod. to high
Platysenta vecors (9696)	pupa?	none?				no?
Platysenta sutor (9699)	migr	none				no
Condica cupentia (9713)	migr	none				no
Condica confederata (9714)	migr	none				no
Emarginea percara (9718)						unknown
Ogdoconta cinereola (9720)	pupa?	none?				no?
Stiriodes obtusa (9725)						unknown

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Amolita fessa (9818)						unknown
Amolita obliqua (9819)						unknown
Amolita roseola (9821)		part				possible
Acrapex relicta (9872.1)						unknown
Amphipyrinae New Genus 2, Species 2 (9872.2)				yes		no
Lithophane patefacta (9886)	adult	full	mid			possible
Lithophane laceyi (9908)	adult	full	mid			possible
Eupsilia vinulenta (9933)	adult	full			very low	no?
Sericaglaea signata (9941)	adult	full			very low	no?
Xystopeplus rufago (9942)	adult+pupa	full	early-mid		mod. high	high
Metaxaglaea viatica (9944)	egg	full	late			possible
Metaxaglaea semitaria (9945)	egg or larva	full?	late		very low	no?
Metaxaglaea australis (9945.1)	egg	full	late			possible
Metaxaglaea violacea (9945.2)	egg	full	mid			possible
Epiglaea apiata (9947)	egg	full	early-mid			high
Chaetaglaea tremula (9949)	egg	full	early-mid			high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Chaetaglaea sericea (9950)	egg	full	late		very low	no
Chaetaglaea fergusoni (9950.1)	egg	full	early-mid			high
Sunira bicolorago (9957)	egg	full			very low	no?
Sutyna privata teltowa (9989.01)	egg	full	mid?			high
Feralia major (10007)	pupa	full	mid			possible
Psaphida styracis (10016)	pupa	full	mid			possible
Psaphida resumens (10019)	pupa	full	early-mid		very high	high
Copivaleria grotei (10021)	pupa	full	mid			possible
Homohadena badistriga (10059)	egg	full	mid-late			possible
Lepipolys perscripta (10154)	pupa	full	early			high
Anepia capsularis (10317)	pupa	none				no
Lacinipolia laudabilis (10411)	larva?	part	early			mod. to high
Lacinipolia implicata (10414)	larva	full	late?			high
Pseudaletia unipuncta (10438)	?+migr	part	all?			mod. to high
Leucania linita (10440)	larva?	full	late+early			mod. to high
Leucania incognita (10450)						unknown

Species (Moths of North America Checklist No.)	**Over wintering Stage**[1]	**Estimated Larval Exposure**[2]	**Probable Instars Exposed**[3]	**Borer/ Internal Feeder**	**Btk Assay**	**Overall Potential Risk from Btk**
Leucania latiuscula (of Forbes) (10454)	migr	none				no
Leucania scirpicola (10455)	larva?+migr	part	early+late			mod. to high
Leucania adjuta (10456)	larva?+migr	part	all			mod. to high
Leucania inermis (10459)	larva?	part	late			possible
Orthosia revicta (10490)	pupa	full	early-mid		none	no
Orthosia alurina (10491)	pupa	full	mid-late		very low	no
Orthosia hibisci (10495)	pupa	full	all?		none	no
Himella intractata (10502)	pupa	full	mid			possible
Egira alternans (10517)	pupa	part	mid-late		low to mod	possible
Achatia distincta (10518)	pupa	full	mid			possible
Morrisonia mucens (10519)	pupa	full	early			high
Morrisonia confusa (10521)	pupa	full	early			high
Morrisonia n. sp. (10521.2)	pupa	part	early			mod. to high
Protorthodes oviduca (10563)	larva	full	late+early			mod. to high
Ulolonche culea (10567)	pupa	full	early-mid			high
Orthodes crenulata (10585)	larva	full	late+early			mod. to high

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Tricholita signata (10627)	egg or larva	full	mid?			high
Agrotis gladiaria (10648)	larva	part	late			possible
Agrotis venerablis (10651)	larva	full?	mid-late			possible
Agrotis n. sp. 1 nr. buchholzi (10654.1)	prepupa	full	early			high
Agrotis malefida (10661)	larva?+migr	part	all?			mod. to high
Agrotis ipsilon (10663)	larva?+migr	part	all?			mod. to high
Agrotis subterranea (10664)	larva?+migr	part	all?			mod. to high
Feltia jaculifera (10670)	larva	part	late			possible
Feltia herilis (10676)	larva	full?	late?			high?
Eucoptocnemis fimbriaris (10694)	larva	full	late			possible
Eucoptocnemis dapsilis (10696)	larva?	full?	late			possible
Trichosilia manifesta (10698.1)	prepupa	full	early			high
Trichosilia geniculata (10698.2)	larva	full?	late			possible
Euagrotis lubricans (10901)	larva?	full	all?			mod. to high
Euagrotis illapsa (10903)	larva	full	late+early			mod. to high
Anicla infecta (10911)	migr	none				no

Species (Moths of North America Checklist No.)	Over wintering Stage[1]	Estimated Larval Exposure[2]	Probable Instars Exposed[3]	Borer/ Internal Feeder	Btk Assay	Overall Potential Risk from Btk
Peridroma saucia (10915)	larva?	full	all			mod. to high
Xestia dolosa (10942.1)	larva	full	late			possible
Xestia badinodis (10955)	larva	part	late			possible
Anomogyna elimata (10967)	prepupa	none				no
Anomogyna youngii (10970)	larva	full?	late			possible
Hemipachnobia subporphyrea (10993)	larva	full	early			high
Cerastis tenebrifera (10994)	pupa	full	early			high
Metalepsis fishii (10997)	pupa	full	mid			possible
Choephora fungorum (10998)	larva	none?				no?
Abagrotis alternata (11029)	larva	full	late		none	no
Rhodoecia aurantiago (11065)	pupa	none				no
Helicoverpa zea (11068)	pupa+migr	none				no
Heliothis subflexus (11070)	pupa	none				no
Heliothis virescens (11071)	pupa	none				no
Schinia scissoides (11099)	pupa	none				no
Schinia septentrionalis? (11110)	pupa	none				no

SPECIES (Moths of North America Checklist No.)	OVER WINTERING STAGE[1]	ESTIMATED LARVAL EXPOSURE[2]	PROBABLE INSTARS EXPOSED[3]	BORER/ INTERNAL FEEDER	BTK ASSAY	OVERALL POTENTIAL RISK FROM BTK
Schinia sordida (11112)	pupa	none				no
Schinia siren (including inclara) (11115)	pupa	none				no
Schinia tuberculum (11116)	pupa	none				no
Schinia lynx (11117)	pupa	none				no
Schinia arcigera (11128)	pupa	none				no
Schinia jaguarina (11132)	pupa	none				no
Schinia rivulosa (11135)	pupa	none				no
Schinia nubila (11137)	pupa	none				no
Schinia saturata (11140)	pupa	none				no
Schinia trifascia (11149)	pupa	none				no
Schinia gloriosa (11171)	pupa	none				no
Schinia sanguinea (11173)	pupa	none				no
Schinia nundina (11177)	pupa	none				no
Schinia carolinensis (11202)	pupa	none				no

[1] Under overwintering stage, migr. Indicates a species that does not overwinter in the project area. Question marks indicate uncertainties.
[2] Under estimated larval exposure, none indicates 10 percent or less of larvae were at risk of exposure, part indicates 11 percent to 89 percent of larvae were at risk, and full indicates 90 percent or more were likely to be exposed.
[3] Under probable instars exposed, early indicates first or second instars, late indicates one of the last two instars, mid indicates: ntermediate instars, and early and late indicates overlap of cohorts

APPENDIX C: Species Associated With Distinctive Habitats and Rare Species in the Eradication Project Area

SPECIES[1]	RANGE[2]	HOST PLANTS	NHP RANK[3,4]	
			STATE	GLOBAL
LONGLEAF PINE AND WIREGRASS – GENERAL				
Semiothisa distribuaria	sCP: NC->FL->AK->TX	Conifers: pine (longleaf only?)	S4	G4
Tolype minta	sCP: [NC->]SC->FL	Conifers: pines (longleaf only in NC?)	S2S3	G4
Gabara pulverosalis	seCP: sNJ->VA,NC->FL	Graminoids: wiregrass?	S2S3	G4
Euagrotis lubricans	seCP: NC->FL	Graminoids: wiregrass?	S3?	G4
PINE SAVANNAS, OPEN BOGS, AND WET SWALES				
Scopula purata	CP: NH->FL->MS	Forbs: dandelion (in laboratory)	S3?	G4
Eubaphe meridiana	E: NY->FL;KY->MS	Unknown	SU	G4G5
Holomelina laeta	E: N.S.[->NC];Man, SD->KY	Forbs: Taraxacum, Plantago (in laboratory)	SU	G4G5
Gabara distema humeralis	S: NC->FL;TN->AR->AL (w.ssp. in TX)	Graminoids: grasses?	S2S3	G4
Gabara n. sp.	?->NC->?	Unknown	SU	GU
Doryodes bistrialis	seCP: NC->FL	Graminoids	S3S4	G3G4
Exyra fax	N: eCan,ME->NC; Great Lakes,Man.	Forbs: Sarracenia purpurea	S3?	G4
Exyra ridingsii	sCP: NC->FL->AL	Forbs: Sarracenia flava	S3?	G3G4
Exyra semicrocea	sCP: NC->FL->TX (including sAPP)	Forbs: Sarracenia spp.	S2S3	G4
Spartiniphaga carterae	eCP: NJ;NC	Grasses: Calamovilfa brevipilis	S2S3	G2G3
Papaipema appassionata	eCP: N.S.->FL;Great Lakes	Forbs: Sarracenia spp.	S2S3	G4
Papaipema eryngii	E: [NC]; IL	Forbs: Eryngium yuccifolium	S1	G1G2
Amolita fessa	E: NY->FL;WS->TX	Graminoids: grasses	S5	G5
Leucania incognita	seCP: [NC->]FL	Graminoids	SU	G?

SPECIES[1]	RANGE[2]	HOST PLANTS	NHP RANK[3,4]	
			STATE	GLOBAL
Hemipachnobia subporphyrea	eCP: NC	Forbs: Dionaea	S1S2	G1G2
Schinia sordida	seCP: [NC-]FL	Unknown	SU	G?
Schinia jaguarina		Forbs: Baptisia	SU	G4
Schinia gloriosa	E: NC->FL;NE,IL->TX	Forbs: Liatris	SU	G4
Schinia sanguinea	sCP: NC->FL->TX	Unknown	SU	G4Q
Schinia carolinensis	seCP: NC->FL	Unknown	S2S3	G?
WET PINE FLATWOODS				
Cyclophora culicaria	eCP: NJ->GA,FL	Shrubs: Leiophyllum, possibly also Ilex glabra (reared from larvae found on Ilex; J.B. Sullivan, pers. comm.)	S3?	G4
Datana ranaeceps	CP: L.I.->FL;AR	Shrubs: Leucothoe, Lyonia (but not Vaccinium or Andromeda, as has been reported)	S2S3	G4
Acronicta sinescripta	sCP: [NC->]SC->FL->LA	Shrubs?; Forbs?	S1S3	G?
Agrotis n. sp. 1 nr. buchholzi	sCP: NC	Shrubs: Pyxidanthera barbulata	S2S3	G2G3
SHRUBBY PEATLANDS				
Glena cognataria	eCP: N.S.->FL->LA	Shrubs: Vaccinium, Prunus	S4	G4G5
Stenaspilatodes antidiscaria	eCP: NJ->FL	Unknown (Ericaceae are accepted in captivity but cannot be reared on them)	S3S4	G4
Metarranthis lateritiaria (of Guenee)	sCP: NC->GA->?	Shrubs: Ericaceae?, Clethra?	S1S3	G3G4
Metarranthis n. sp. 1	sCP: NJ->NC->?	Shrubs: Ericacaea?	S2S3	GU
Callosamia securifera	sCP: NC->FL->MS	Hardwoods: sweetbay	S2S3	G4
Sphinx gordius	eCP: MA,RI->NJ->FL	Shrubs: Vaccinium, Gaylussacia, Comptonia peregrina, Myrica (Malus and conifer records refer to S. poecilius)	S3?	G4
Spilosoma dubia	E: Can->NY->FL->eTX	Hardwoods: Prunus; Shrubs: Vaccinium; Forbs: Plantago and probably many other herbs	S3S4	G?

Species[1]	*Range*[2]	*Host Plants*	*NHP Rank*[3,4]	
			State	**Global**
Dysgonia similis	seCP:[NC->]FL	Unknown	S2S3	G?
Argyrostrotis sylvarum	seCP: [NC->]FL	Shrubs: Lyonia	S4	G?
Argyrostrotis erasa	seCP: [NC->]FL	Shrubs?	S4	G?
Argyrostrotis deleta	seCP: [NC->]FL	Shrubs?	S4	G?
Catocala praeclara	E: N.S.->FL;MN->KS	Shrubs: Aronia, Amelanchier (rarely)	S4	G4G5
Nola clethrae	eCP: MA->NC->GA	Shrubs: Clethra	S4S5	G5
Acronicta lanceolaria	E: ME,MA->FL;Man.->KS,MO	Hardwoods: willow, poplar, cherry; Shrubs: blueberry, sweet fern,	S3?	G4
Epiglaea apiata	N: N.S.->SC;sCan->WI	Shrubs: blueberries and cranberry	SU	G5
Anomogyna youngii	N: Lab.->NJ[->NC];OH	Conifers: larch; Shrubs: Vaccinium, Gale, Chamaedaphne	S3S4	G5
Metalepsis fishii	N: N.Br.,Que->ME,MA->NJ[->NC];OH	Shrubs: blueberry	SU	G4
Atlantic White Cedar Forests				
Semiothisa multilineata	E: MA->FL;MO,AR	Conifers: Juniperus, Chamaecyparis	S4	G4G5
Glena plumosaria	seCP: NJ[->NC->]AL,MS	Conifers: Juniperus, Chamaecyparis thyoides	S3S4	G4
Hypagyrtis brendae?	seCP: ?->NC->?	Conifers: Chamaecyparis thyoides	S2S3	G?
Patalene olyzonaria puber	E: NH->FL;WS->MO->TX	Conifers: Juniperus, Chamaecyparis, Pinus?	S5	G5
Canebrakes				
Acrapex relicta	seCP: VA->GA	Grasses: cane	S3?	G4?
Amphipyrinae, New Genus 2, Species 2 (of Quinter)	SE: VA->FL;MO->MS	Grasses: cane	S3?	GU
Swamp Forests and Levee Forests				
Semiothisa aequiferaria	sCP: NC->FL->TX	Conifers: Taxodium	S4	G4G5
Anacamptodes cypressaria?	seCP: ?->NC->?	Conifers: Taxodium?	S2S3	G?
Anacamptodes pergracilis	S/CP:eVA->FL->TX	Conifers: Taxodium	S4	G4G5

Species[1]	*Range*[2]	*Host Plants*	*NHP Rank*[3,4]	
			State	**Global**
Isoparce cupressi	S: [VA,NC->]SC->FL;AR->TX	Conifers: bald cypress	S3S4	G4G5
Cutina distincta	seCP: [NC->]FL	Conifers: Taxodium	S4	G4G5
Cutina albopunctella	sCP: [NC]->?	Conifers: Taxodium	S4	G4G5
Cutina aluticolor	sCP: [NC]->?	Conifers: Taxodium	S4	G4G5
Cutina arcuata	sCP: [NC]->?	Conifers: Taxodium	S4	G4G5
Catocala marmorata	E: VT,NY->SC;WI->MO	Hardwoods: willow, cottonwood	S1S3	G4
Catocala lincolnana	seCP: [NC->]FL->AR	Hardwoods: Crataegus	S1S2	G3?
Sandhills and Other Xeric Woodlands				
Semiothisa ordinata	sCP: [NC->]FL	Forbs: Amorpha	S2S3	G?
Nemoria bifilata bifilata	CP: NY,NJ->FL->LA	Hardwoods: oaks, including blackjack and bear oak; Shrubs: Rhus copallina (in laboratory)	S3?	G4
Idaea eremiata	CP: NJ->GA->TX->AZ	Unknown	SU	G4
Idaea violacearia	E: NJ->FL;Great Lakes	Unknown	S3?	G4
Idaea ostentaria	CP: [NC->]FL	Unknown	S3?	G?
Cicinnus melsheimeri	E: sOnt,MA->FL;WI->TX	Hardwoods: scrub oaks	SU	G4
Hyparpax aurora	E: N.S.->GA;MN->KS,AR->LA	Hardwoods: scrub oaks (but not Viburnum, as has been reported)	SU	G4
Crambidia pura	CP: NY->NJ->FL;KY	Lichens	SU	G4
Cisthene subjecta	seCP: NJ->FL	Lichens	SU	G4
Pygarctia abdominalis	eCP: NJ->FL	Forbs: Ipecac?, other euphorbias?	S1S2	G3G4
Dasychira leucophaea	seCP: sNJ->FL	Hardwoods: oak? (probably not -- DFS), poplar	S3?	G4
Bleptina inferior	E: sNJ->FL	Dead Leaves	S3?	G4
Hemeroplanis habitalis	seCP: NC->FL	Unknown	SU	G5
Hormoschista latipalpis	S: D.C.->FL;KY->MS	Unknown	SU	G5

Species[1]	Range[2]	Host Plants	NHP Rank[3,4]	
			State	Global
Phoberia orthosioides (of Ferguson)		Hardwoods: xeric oaks	S3S4	G4
Ptichodis bistrigata	SE: eNJ->FL;MO->TX	Unknown	S2S3	G3
Catocala amestris	E: NC->FL;WI,SD->IL->TX	Forbes: Amorpha; Hardwoods: locust	S1S2	G4
Catocala jair	eCP: NJ->FL	Hardwoods: xeric oaks	S1S3	G4
Hyperstrotia flaviguttata	E: MA->FL;sOH->TX	Hardwoods: oak	SU	G4G5
Elaphria festivoides complex		Hardwoods: box elder	SU	G4
Emarginea percara	sCP: sVA->FL	Epiphytes: Tillandsia?, mistletoe	SU	G?
Chaetaglaea fergusoni	S: [NC->]SC->FL->LA	Unknown	SU	G4?
Eucoptocnemis dapsilis	sCP: [NC->]FL	Unknown	S2S3	G4
Trichosilia manifesta	E: MA->NJ[->NC];IL,OH->TN	Forbs: clover (in lab.)	S2S3	G4
Maritime Evergreen Forests and Scrub				
Cymatophora approximaria	eCP: NJ?->eVA->FL	Hardwoods: oaks, including live oak (but not on Smilax, as apparently based on Abbott)	S4	G4G5
Heterocampa astarte	seCP: [NC->]FL	Hardwoods: live oak, other oaks?	S4	G4
Dyspyralis n. sp.	?->NC->?	Unknown	SU	G?
Metalectra albilinea	seCP: [NC->]FL	Unknown	S3?	G?
Litoprosopus futilis	sCP: [NC->]SC->FL->MS	Palms: saw palmetto	SU	G4G5
Panopoda repanda	S: NC->FL;KY->TX	Hardwoods: live oak;	S4	G4G5
Drasteria graphica	CP: ME->FL->MS;Great Lakes	Shrubs: blueberry, Hudsonia	S2S3	G5T4
Metria amella	sCP: [NC->]FL	Hardwoods: live oak	S4	G4G5
Zale declarans	sCP:[NC->]FL	Hardwoods: live oak	S2S3	G4G5
Catocala messalina	seCP: VA->FL->LA->TX;KS	Hardwoods: live oak?	S2?	G4
Mesic Hardwood Forests				
Scopula ordinata	E: NC->FL->MS	Forbs: Trillium catesbaei	S2S3	GU

Species[1]	*Range*[2]	*Host Plants*	*NHP Rank*[3,4]	
			State	**Global**
Nematocampa baggetaria	sCP: NC->FL->LA	Unknown	S2S3	GU
Notodontidae, New Genus 1	S: ?->NC->?	Unknown	S1S2	GU
Dasychira atrivenosa	sCP: eMD->FL->eTX,AR	Hardwoods: Liquidambar (in laboratory)	S2?	G4
Other Significantly Rare Species of Various Habitats				
Ceratonyx satanaria	eCP: [NC->]FL	Unknown	S2?	GU
Eupithecia peckorum	S: [NC];MO->MS->LA->TX	Unknown	S2?	G?
Macrochilo louisiana	E: eCan.,ME->FL->MS->LA;OH	Graminoids: sedges?	S2S3	G
Dysgonia smithii	SE: NJ->FL;OH?,MO->TX	Unknown	S2S3	G4
Cerma cora	E: ME->GA;Ont.->IO->TX	Hardwoods: pin cherry, other Rosaceae? (hawthorn?)	S2S3	G4
Meropleon diversicolor sullivani	sCP: ?->NC->?	Graminoids	S1S3	G4TU
Lithophane laceyi	sCP: NC->MS	Hardwoods?	S1S3	GU

1. Species in bold face were listed as significantly rare in LeGrand and Hall (1997). A few additional species have also been added to this list since the last edition was published, including *Papaipema eryngii.*
2. Distribution along the Atlantic Slope is given first, from north to south; Mid-western range is given second, followed by western ranges. E = Eastern United States and Canada; N = Northern United States; S = Southern United States; CP = Coastal Plain; [ ] = not included in published range descriptions. Lower case letters prefixed to some of these codes include e for east, and s for south.
3. State ranks are analogous but refer to the distribution of a species within a state instead of its entire range.
4. Global Ranks estimate the rarity or commonness of a species rangewide, according to the following conventions:

   G1 – Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Number of extant populations is estimated to be within one to five.

   G2 – Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range. Number of extant populations estimated to be within six to twenty.

   G3 – Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single physiographic region) or vulnerable to extinction due to other factors throughout its range. Number of extant populations estimated to be within 21-100.

   G4 – Uncommon to rare but apparently secure globally. Number of extant populations estimated to be within 100-1,000.

   G5 – Demonstrably secure globally, although possibly rare in some parts of its range, particularly at the periphery. Number of extant populations estimated to be over 1,000.

   GU – Global rank cannot be estimated based on current data.

APPENDIX D: New State Records

This assessment is based primarily on review of the literature. Institutional collections that were consulted include the North Carolina State University Collection of Insects, the Insect Collection of the North Carolina Department of Agriculture, U.S. National Museum, and American Museum of Natural History. Other collections, however, were not surveyed for previously collected specimens.

Species	Range[1]
Semiothisa ordinata	sCP: [NC->]FL
Pimaphera percata	sCP: [NC->]FL
Ceratonyx satanaria	eCP: [NC->]FL
Lobocleta plemyraria	E: NJ->FL;SD->TX
Lobocleta peralbata	S: [NC->]SC->FL;TX
Idaea ostentaria	CP: [NC->]FL
Cyclophora culicaria	eCP: NJ->GA,FL
Cycnia inopinatus	E: NJ->FL;SD->TX
Bleptina sangamonia	E: [NC->]FL;IL,OH->TX
Metalectra albilinea	seCP: [NC->]FL
Zale phaeocapna	E: nNY->PA->FL;OH->AL
Papaipema eryngii	E: [NC];IL,KY,OK
Trichosilia manifesta	E: MA->NJ[->NC];IL,OH->TN
Schinia scissoides	seCP: [NC->]SC->FL
Schinia siren	S: [NC->]FL->Southwest
Eucoptocnemis dapsilis	sCP: [NC->]FL

1. Distribution along the Atlantic Slope is given first, from north to south; Mid-western range is given second, followed by western ranges. E = Eastern United States and Canada; N = Northern United States; S = Southern United States; CP = Coastal Plain; [ ] = not included in published range descriptions. Lower case letters prefixed to some of these codes include e for east, and s for south.

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